EIGHTH ANNUAL REPORT

OF THE

UNITED STATES GEOLOGICAL SURVEY

TO THE

SECRETARY OF THE INTERIOR

1886-'87

BY

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DIRECTOR

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EIGHTH ANNUAL REPORT

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OF THE

UNITED STATES GEOLOGICAL SURVEY.

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DEPARTMENT OF THE INTERIOR,
UNITED STATES GEOLOGICAL SURVEY,
Washington, D. C., July 25, 1887.

SIR: I have the honor to transmit herewith a report of the operations of the Geological Survey for the year ending June 30, 1887.

In directing the work of the organization under my charge I have had frequent occasion to invoke your aid and counsel, and I beg to tender you my grateful acknowledgments for the same.

I am, sir, with great respect, your obedient servant,

J. W. Powell
Director.

Hon. L. Q. C. LAMAR,
Secretary of the Interior.

EIGHTH ANNUAL REPORT OF THE UNITED STATES GEOLOGICAL SURVEY.

By J. W. Powell, Director.

BUSINESS ORGANIZATION OF THE SURVEY.

INTRODUCTORY REMARKS.

The Geological Survey was organized, with Mr. Clarence King as Director, in March, 1879. In March, 1881, Mr. King resigned and the present Director was appointed. From its organization to the present time the Survey has steadily grown as Congress has enlarged its functions and increased its appropriations. During this time the scientific organization has gradually developed to the condition set forth in the last annual report. It seems advisable now to describe fully the business organization and methods of the Survey, which has heretofore been done only in part.

Under the act of July 7, 1884, a joint commission was created to consider the organization of certain scientific bureaus. In the volume of testimony prepared by that commission the business operations of the Geological Survey were in part set forth; but this partial presentation was unsystematic, the facts recorded being elicited in irregular order by interrogatories arising in the course of a long investigation. It is designed here to make a more thorough exposition of the subject.

The business system of the Geological Survey is subordinate to the scientific organization and its character is dependent thereon. The development of the divisions of the Survey whose function is the transaction of business has therefore followed the development of the purely scientific divisions, and every modification of plan for the scientific work may carry with it some modification of the business organization.

GENERAL PLAN OF THE SURVEY.

The function of the Geological Survey, as defined by its organic law, is "the geological survey and the classification of the public lands, and examination of the geological structure, mineral resources, and products of the national domain," and it is directed "to continue the preparation of a geological map of the United States." This involves original research in many distinct lines, all intimately related and together covering a considerable field. For the prosecution of these researches in a systematic manner there has been organized in the Survey, as set forth in earlier reports, a number of scientific divisions: a division of geography, several divisions of geology and paleontology, a division of chemistry and physics, a division of forestry, a division of statistics, &c.

In the consideration of this subject certain characters of a geological survey should be kept in view.

In the prosecution of a land parceling survey, it is generally the case that the plan of the work is developed in all its details before the survey is initiated; and the work is thus one of applied science, in which no original research is required and a fair degree of training, intelligence, mechanical skill, and experience in the work suffices for its satisfactory prosecution. In cadastral surveys, also, the plan is generally completed before the work is begun, and the prosecution of the survey is therefore a work of applied science; but intelligence and judgment are frequently required.

The work of making a topographic survey is largely one of applied science after the plan is elaborated. But in the prosecution of a complete topographic survey of a state or country upon a large scale a great variety of features must be recognized and conventions suitable for representing them upon the plane surface of the map must be invented or selected, these conventions requiring modification with the local variations in topographic configuration, amount of culture, &c. in different parts of the area; and it has been found by experience that artistic skill, ingenuity, and creative ability on the part of the topographic surveyor are essential to the best work.

Thus an elaborate topographic survey must involve not only such mechanical skill and experience as are required in the land parceling survey, but also originality, intelligence, and judgment of a high order.

From the nature of the work a geologic survey of a state or country cannot be made in accordance with definite plans formulated in advance, for such a survey involves the discrimination and classification of widely varied and sometimes obscure phenomena in accordance with principles which have to be developed as the work progresses. The work of a geologic survey therefore requires originality, intelligence, and judgment of the highest order, as well as long training and experience. The geologist must be a student and must acquaint himself with the writings of other students in various languages; in order to do the best work he must be familiar with the progress of science in general, and must be particularly well informed concerning the developments of geologic science in all portions of the globe. He must also possess sufficient literary and artistic skill to set forth, both verbally and graphically, the results of his investigations, and a large part of his work must be original and creative.

In the Geological Survey it is recognized that talents of a high order must be secured to prosecute the surveys and researches which it is its function to perform and that every geologist must be an author, actual or prospective.

This important difference between surveys involving only applied science and those involving original research cannot be too strongly emphasized: in the one case the process is one of the application of known principles, and nothing is added to general human knowledge or to intellectual progress; while in the other case the process is one of the evolution of principles themselves, in which every cycle multiplies human knowledge. There is set before the surveyor by applied science a definite task, and a definite time is allowed in which to accomplish it; all of the conditions and elements are known; the factors and the results are alike susceptible of quantitative measurement; and at the appointed time, if the estimate has been carefully made, the task is completed. The surveyor

whose methods involve original research, on the other hand, sees but dimly the task laid before him; the conditions and elements are unknown; neither the factors nor the results can be quantitatively measured; and while the end of a specified period of work may bring tangible results—in the shape of final geologic coloring of a certain area upon the map, in the shape of the discovery and definition of important mineral deposits, or in the shape of new principles affecting materially the industries related to his field of work—it may bring nothing more than new problems, which must be solved before the practical results of his labors can be secured.

The scientific work of the Geological Survey is in part topographic and in part geologic. The topographic work, together with that performed in certain of the accessory divisions of the Survey, is, at least in a measure, work of applied science, and is capable of prosecution in accordance with prearranged plans, but it is in part original and creative; while the geologic work is almost wholly original and creative, involves in only a minor degree the application of known principles, and cannot therefore be definitely prearranged. The principal work of the Survey is geologic; its plans are modified from time to time with its progress and with the growth of geologic science; and there is concurrent modification of the work of the accessory divisions.

There is a third class of work performed in the Survey. In the various scientific divisions money is necessarily expended for salaries, traveling expenses, wages of temporary assistants, field subsistence, and in other ways; and it has been necessary to devise a comprehensive system of regulating and accounting for these expenditures and to organize a clerical and accounting force for that purpose. Moreover, property is acquired by the Survey from time to time in the form of instruments, animals and vehicles, camp equipage, stationery, laboratory apparatus and materials, office equipments, &c.; this property is of exceedingly diverse character, is generally of only limited value in any particular locality, and is acquired and held in all parts of the country, and it has been necessary to devise a comprehensive plan for regulating the cus-

tody and use of such property. Again, property is created in the form of maps, sketches, photographs, manuscripts, collections of minerals and fossils, &c., and the custody, use, and disposition of such property also require regulation. Finally, the published maps and printed reports &c. of the Survey constitute property the disposition of which is regulated by law, and it has been necessary to provide for the distribution of this property to the public in accordance with law and to organize a force to effect such distribution.

To meet these various requirements there has been developed within the Geological Survey a general plan for the conduct of its business affairs, comprehending (1) a fiscal system, (2) a custodial system, (3) a museum system, (4) an illustration system, (5) an editorial system, (6) a document system, (7) a library system, (8) a stationery system, and (9) a correspondence system.

The organization in the business branch of the Survey is necessarily less complete than the differentiation of function. There is a definitely organized division of disbursements and accounts; but all business transacted in this division is carried on under the immediate and constant supervision of the Director, and the division is thus a part of the executive machinery of the Survey. Moreover, there are several disbursing agents not immediately connected with this division, most of whom are geologists or topographers. In the same division there is an officer who is the general custodian of the public property in the possession of the Survey and who accounts for all such property not specifically charged to the other custodians, most of whom are heads of scientific divisions and their assistants. There is a division by which the distribution of the publications of the Survey is effected, in which the custody of the library is vested, and by which that part of the correspondence of the Survey relating to publications and to the purchase and exchange of books, maps, &c. is carried on. There is also a division of illustrations, which has charge of the drawings, sketches, photographs, and photographic apparatus and materials, and by which the illustrations (other than maps) required for the publications of the Survey are prepared; but the

collection and elaboration of the material for maps, the preparation of this material for the engraver, and the revision of map proofs &c. are performed in the division of geography, in which the custody of map material is vested. There is an editorial and miscellaneous division, in which the manuscripts designed for publication by the Survey are put in condition for the press, the proofs revised, &c.; the general correspondence of the office is also in charge of this division. Property acquired and produced by the Survey in the form of collections, minerals, fossils, &c. remains in the custody of the division by which the material is acquired or produced until its investigation is completed, when it is transferred to the National Museum, generally through the petrographic division, the chemic division, or the paleontologic divisions, the heads of which are honorary curators of the Museum.

There is thus a combination of functions running through not only the non-scientific branch of the Survey, but extending also to the scientific branch, and, in so far as is practicable without loss of efficiency on the part of the heads of the different scientific divisions, it is the policy of the Survey to charge them with the disbursement of funds in their divisions and with the custody of the property used, acquired, and produced therein. This arrangement has been found expedient partly because it is economical and partly because it tends to promote harmony and unity throughout the organization by keeping the different officers of the Survey familiar with the operations of divisions other than their own.

Thus the operations of the Geological Survey belong to three branches, in each of which the grade of work is distinct. The principal branch of work is original research, or work of pure science, which cannot be antecedently planned except in general terms and in which the results are seldom susceptible of quantitative measurement. There is a collateral branch of work—that involved in the topographic survey growing out of the want of maps of the country suitable for geologic purposes—which is partly a work of applied science, but in which originality and creative ability are involved in large measure. And there is a third branch of the work of the Survey, com-

prehending its business operations, depending upon the others and modified by their requirements from time to time, which occupies the same plane as that of commercial and financial institutions and administrative departments generally, in which the work may be antecedently planned and systematically controlled at every stage and in which the results are susceptible of quantitative measurement in commonly recognized units.

The operations of this subordinate branch of the Survey are carried on in accordance with a comprehensive plan, to the development of which much thought has been given. Its organization will be described in detail, and for the sake of clearness its operations will be presented under the systems or departments to which they logically belong rather than under the administrative divisions in which for economic reasons they are grouped.

THE FISCAL SYSTEM.

PRINCIPLES CONTROLLING THE SYSTEM.

There are four fundamental considerations involved in the disbursement of the money appropriated for the Geological Survey. They are as follows:

(1) Every facility should be afforded to the scientific work of the Survey, as that is the purpose for which the money is appropriated; (2) there should be no unnecessary or extravagant expenditures; (3) the public money should be protected against depredation; and (4) every Government agent should be required to establish the integrity of his transactions.

It is evident that exclusive attention to the expedition of the work might lead to extravagance, while a parsimonious policy might impede the work by depriving it of necessary facilities. Proper administration demands the exercise of discriminating judgment in each individual case.

Every restrictive regulation to prevent extravagance adds to the labor of those engaged in research, adds to the amount of clerical work to be performed, and to some extent obstructs and delays the performance of scientific work. It is quite possible so to complicate the fiscal and custodial systems of a

scientific bureau that carrying them on shall consume a large part of its energy and correspondingly diminish its results.

It is, moreover, a familiar fact that regulations for the prevention of dishonest practices, while they are designed to conserve the means for the conduct of the proper work of the Bureau, are in themselves a source of expense. Protection from depredation costs money.

The relation of the disbursing agent to the Government differs in an important respect from the relation between a private business agent and his employer. In the latter case, the employer is an individual, having a personal interest in the business transacted and a personal acquaintance with his agents. In the former case the employer is impersonal and cannot directly supervise the transactions of the agent. The disbursing agent is, therefore, essentially a trustee and the funds in his charge are trust funds; so that it is not without reason that he is required to submit to a system of restrictive regulations which in ordinary commercial business might be regarded as onerous. The private employer presumes the integrity of his agent until the contrary is proved; the Government requires its agents to establish the integrity of all their transactions.

APPROPRIATIONS.

The funds for carrying on the work of the United States Geological Survey are appropriated by Congress in three portions: The first, in the legislative act, for the payment of stated salaries of the individuals composing the permanent force of the Survey; the second, in the sundry civil act, for the payment of stated salaries of the permanent scientific assistants; and the third, also in the sundry civil act, for the payment of the temporary employees in the field and office and for the various other necessary expenses of the Survey.

As shown in the financial statement appended hereto, the appropriations for the past year were under the legislative act $35,540 and under the sundry civil bill $67,700 for scientific assistants and $400,000 for other necessary expenses. The funds required in the transaction of the current business of the

Survey are drawn from the Treasury on requisition of the Secretary of the Interior and on the books of the Treasury Department are placed to the credit of the chief disbursing clerk or one of the disbursing agents. All the disbursing officers of the Survey are bonded.

METHOD OF ALLOTMENT.

As stated at length in the last report, the Survey is organized into divisions, which are sometimes further divided into sections and subsections, and each division, section, or subsection is charged with certain work in a certain field.

Before the close of each fiscal year the plan for the ensuing year is formulated by the Director, after conference with the heads of the various divisions and sections in the Survey, and a stated sum is allotted to the chief of each for use in carrying forward the work of which he has charge during the fiscal year for which the new appropriation is made. The chief of division or section thus assumes charge of a special subject of investigation or a certain field of work; he is responsible to the Director, through the fiscal branch of the Survey, for confining the cost of the investigation to the sum allotted and for the propriety and economy of his expenditures; he is also responsible to the Director for the quality and quantity of the work performed; and, since all reports or maps made by him are published under his name, the incentive to do all that can be done with the money allotted is of the highest nature. In large measure he is an independent investigator engaged in his ideal work, in the course of which he in part devises his own plans and develops his own problems, executing his plans and solving his problems in his own way; but his work is under the general supervision and control of the Director and his operations are limited by his allotment and by the business regulations of the Survey.

It is believed that this method of allotment in the scientific branch of the Survey is productive of good results. The chiefs of the scientific divisions are scientific men, selected for their eminence and ability and for their proficiency in the special lines of work to which they are severally assigned; and it is

not only a reasonable presumption, but it is found by experience to be true, that investigations are pursued as economically as possible in order that results of the greatest value may be secured by the means provided.

The plan for the year's work thus developed within the Survey is submitted to the Secretary of the Interior for examination and approval at the commencement of each fiscal year.

METHODS OF MAKING PURCHASES.

There are three methods of making purchases: (1) Many articles are obtained through the Interior Department under its standing contracts, and the amount of the cost of such articles is transferred from the appropriations of the Geological Survey to the contingent fund of the Interior Department by certificate of the Treasurer; (2) articles are purchased from the lowest bidder under the competitive system; (3) when it is inexpedient, by reason of great delay or the cost of transportation from the general office to the field, to obtain the articles by these methods, provision is made to purchase articles in any part of the country at current retail rates under the authority of section 3709 of the Revised Statutes, viz: "When immediate delivery or performance is required by the public exigency, the articles or service required may be procured by open purchase or contract, at the place and in the manner in which such articles are usually bought and sold or such service engaged between individuals." In such case the following certificate is placed upon the voucher:

No advertisement. Public exigency required the immediate delivery of the articles [*or* performance of the services].

Purchases are made on requisitions, generally by chiefs of division, countersigned by the chief clerk, and sometimes formally approved by the Director. In order to facilitate the keeping of accounts purchases are made so far as may be desirable in the city of Washington, and provision has been made for keeping a record thereof in a simple and uniform manner. Commonly the order is made upon a blank, on which the article or property ordered is clearly described and the allotment against which the price is to be charged also specified. This

order is made out in duplicate: the original is transmitted to the dealer and returned with the bill and is finally filed with the purchase voucher, and the duplicate is preserved by the property clerk, whose special functions are described in another paragraph. In certain cases letters are substituted for the orders made out upon the printed forms, but these are press-copied and the method of procedure remains the same.

VOUCHERS.

Three classes of vouchers are used, namely, salary vouchers, traveling expense vouchers, and purchase vouchers.

The employees of the Survey fall into three classes: The first appointed by the Secretary of the Interior, upon the recommendation of the Director, as scientific specialists; the second appointed by the Secretary of the Interior, in accordance with the civil service law; and the third, comprising temporary field assistants, employed by the day or month for special duty by the Director or other officers of the Survey.

The salary of each employee is paid upon a voucher, which consists of a bill for the service, a certificate that the service has been rendered, and a receipt for the amount specified; and before payment is made the account is certified by the chief of division or section and the receipt is signed by the payee. In certain cases payrolls are substituted for the separate vouchers, simply for convenience; but the payroll, like the voucher, consists of bill, certificate, and receipt, and is certified by the officer in charge. As in other governmental organizations, the necessary traveling and living expenses of employees engaged in the performance of field duty are paid upon presentation of suitable vouchers. In the Geological Survey actual expenses only are paid; there are no allowances, no expenditures are commuted, and the living expenses of employees at stations are at their own cost.

The traveling expense voucher in like manner consists of a bill, a certificate, and a receipt, which must be duly signed before the amount is paid. Each traveling expense voucher is moreover accompanied by an order authorizing the journey. At the beginning of each fiscal year chiefs of division are

authorized to undertake and order such journeys as may be required in the prosecution of the work under their charge, and such authority covers their journeys for the year, the original order or a suitable extract from it accompanying each voucher. Other officers and employees of the Survey make journeys only under special orders, which are appended to the traveling expense voucher, and each voucher is certified by the officer ordering the journey. The regulations of the Treasury Department also require that the correctness of the expense account covered by the voucher shall be certified under oath. In addition every item of the traveling expense voucher (except charges for transportation by rail, steamboat, or stage at current rates or single meals en route) must be attested by a subvoucher signed by the person to whom payment was made.

Each purchase voucher likewise consists of bill, certificate, and receipt. The bill and receipt are signed by the party from whom the purchase is made, and the certificate, setting forth that the account is correct and just, that the purchase was necessary, and that the articles have been received and applied to the use of the Survey, is signed by the officer in charge. Each purchase voucher bears in addition the certificate of a duly authorized custodian that the property purchased has been transferred to his custody.

Vouchers properly signed and certified are paid upon presentation to the disbursing officer for the division. They are then audited in the office of the chief disbursing clerk and finally examined, approved, and certified by the Director, after which they are transmitted through the Secretary of the Interior to the Treasury Department for final settlement. It is the plan of the Director to have the accounts of the disbursing officer substantially audited in his own office, where all the circumstances affecting their integrity and propriety are known, and to have every expenditure so fully explained on the voucher or accompanying papers that the accounting officers of the Treasury may have all necessary pertinent facts submitted to them. Thus far in the history of the Survey every voucher which has been accepted by the chief disbursing clerk and approved by the Director has been found satis-

factory to the Comptroller of the Treasury and has been allowed in full.

All vouchers are made in duplicate. The original set is forwarded by the chief disbursing clerk, through the Secretary of the Interior, to the Auditor of the Treasury, and is used in making settlements, and the duplicate set is retained by the officer making the disbursement.

It will be observed that the voucher system appears somewhat cumbrous, particularly in the case of vouchers for traveling expenses; but the plan upon which they are framed is simple and some detail is unavoidable in carrying out the principles (1) that the documentary authority and responsibility for every transaction shall coincide with the actual authority and responsibility, and (2) that every agent of the Government shall be required to establish the integrity of his transactions.

Administrative authority is necessarily delegated to subordinates in many cases; but in such cases it is not the method of the Survey to permit the documentary authority to remain by conventional fiction with the chief. Accordingly, no person is required to certify to the correctness of a voucher unless the expenditure was made under his immediate supervision or he has every means of knowing the facts concerning it. In the practice of the Survey the chief of a division or party authorizes a journey by a subordinate; the subordinate performs the journey, taking receipts from outside parties for all expenditures except those concerning which the superior officer is informed or may readily inform himself (regular fares, meal rates, &c.), thereby establishing the integrity of each transaction by collateral evidence; and, being perfectly familiar with the circumstances of the entire journey, he makes oath to the correctness of his account so far as the details of the voucher are concerned. The chief of division or party who authorized the journey is then only required to satisfy himself and to certify that the routes of travel coincide with the instructions, that the time occupied was not excessive, that the rates charged are current, and in a general way that the account is correct and just; but, since he is responsible for the journey, he is re-

quired to certify that it was necessary. The proper disbursing officer, after finding that all regulations have been complied with, indorses and pays the account, thus assuming responsibility for its technical accuracy; and finally the Director scrutinizes the voucher, and, if his judgment confirms that of the disbursing officer as to its accuracy and that of the chief of the division or party as to its necessity, certifies it, thus assuming general responsibility to the Federal Treasury for the entire transaction. But the actual responsibility at every stage is fixed by documentary evidence: the Director is protected by the indorsements of the disbursing officer and chief of division, one of whom is bonded and the other as effectively bound by his scientific reputation and desire to accomplish maximum results with the money at his disposal, as already set forth; the disbursing officer is protected by the various persons whose signatures are affixed to the document; the chief of division is protected in turn by the certificate and oath of the subordinate; and the subordinate is protected by the parties with whom his business was transacted and whose signatures are affixed to the subvouchers.

TRANSPORTATION OVER BONDED RAILROADS.

The special laws and departmental regulations relating to transportation of Government agents and property over railroads which have received subsidies and land grants are complex and are modified from time to time as the status of each subsidy or grant changes. Accordingly, provision has been made for securing transportation for members of the Survey force over bonded railroads by means of transportation requests issued by the Department of the Interior. These requests are accepted by railroad companies in lieu of cash and are transmitted by railroad agents through the Secretary of the Interior to the chief disbursing clerk, by whom they are recorded and approved and finally transmitted to the United States Treasury for settlement. Moreover, it is sometimes desirable to reduce to a minimum the sums advanced by assistants for necessary traveling expenses, for which they may not be reimbursed for weeks or even months, and provision has

accordingly been made for securing transportation upon similar requests directed to railroads that are not bonded. Such requests are transmitted through the Interior Department to the central office of the Survey, where they are settled.

Transportation requests are made upon forms signed in blank by the Secretary of the Interior and countersigned by the Director. They are numbered in a continuous series and are charged against the officers to whom they are issued in a book kept for that purpose by the chief disbursing clerk. When such a request is used a certificate that transportation has been furnished upon it is filled out by the person receiving the transportation, and at the same time a coupon certificate of like tenor is mailed to the Secretary of the Interior and finally transmitted to the central office of the Survey, where it is recorded and filed. In addition, the employee receiving transportation on such requests is required to communicate the fact of such transportation and the value thereof to the disbursing officer for the division, by whom all such transactions are reported in the account with the allotment for the division.

Provision is also made for the transportation of property under the system established by the Quartermaster General of the Army. When an officer of the Survey desires to transport bulky property he either turns it over to a quartermaster, after properly addressing the parcels, and requests him to forward it, or, if there is no quartermaster at the point of shipment, he writes to the one nearest that point, describes the shipment, and requests him to send duplicate bills of lading, on the receipt of which the freight is shipped, and the bills of lading, after signature by the agent of the railway, are returned to the quartermaster. The accounts for the transportation of property are transmitted by quartermasters to the War Department and thence to the chief disbursing clerk of the Survey, by whom they are approved and recorded, when they are finally transmitted to the Treasury for settlement.

DISBURSING OFFICERS AND THEIR SPECIFIC DUTIES.

The fiscal operations of the Survey are in charge of a chief disbursing clerk; but it has also been found expedient to ap-

point a number of disbursing agents for field duty. In addition to the Director and chief clerk there are at present ten disbursing agents in the Survey: three of these are employed exclusively in the work pertaining to the fiscal branch of the Survey; four are geologists, two are topographers, and one is a geographer, who merely add the labor of disbursing to their other duties.

The chief disbursing clerk and the disbursing agents have independent accounts with the Treasury; but all requisitions for funds and all quarterly statements accompanied by vouchers pass through the office of the chief disbursing clerk, who keeps an account with the annual appropriations and with each disbursing agent. The following books are used in keeping a record of the office transactions and indicate the character of the business in the office of the chief disbursing clerk and the methods of recording it, viz: (1) A book of letters sent and received, comprising all correspondence relating to the fiscal operations of the Survey; (2) a ledger, in which are kept the accounts with the annual appropriations and with the disbursing agents; (3) a book of requisitions for advances of money from the Treasury; (4) an allotment book, containing an account with each chief of division, in which he is debited with the amount allotted to him and credited with his expenditures; (5) a record of vouchers paid, into which are copied in detail all vouchers paid by the disbursing agents, and which accordingly contains a complete record of each financial transaction of the Survey; (6) a record of bonded railroad accounts, in which are kept the accounts rendered by railroads for transportation of persons and property in accordance with section 5260 of the Revised Statutes; (7) a record of transportation requests issued, in which are recorded the requisitions for transportation of persons and property traveling on public duty over bonded railroads in accordance with the statute last mentioned; (8) a classification of expenditures, in which the various expenditures of the Survey are arranged in schedules; (9) a balance book, in which are kept the quarterly accounts of disbursing officers of the Survey; and (10) a series of books of property received and shipped, containing a record of all collections, specimens, instruments, and other property received and transmitted.

The chief disbursing clerk and the disbursing agents report to the Director weekly their total disbursements, the balance of funds in their personal possession, and the balance in United States depositories. These officers also render quarterly accounts to the Treasury, accompanied by the vouchers paid during the quarter, and a ledger, or abstract, containing a detailed statement of all payments made on the vouchers.

The chief disbursing clerk of the Survey is Mr. John D. McChesney. He has an office in the building occupied by the Survey and employs eight assistants. The disbursing agents, the divisions or sections for which they disburse, and their headquarters are given in the accompanying table:

Disbursing agents of the Survey.

Name.	Position.	Division or section.	Headquarters.
Powell, J. W	Director	General	Washington, D. C.
Pilling, James C	Chief clerk	General	Washington, D. C.
Christie, P. H	Topographer	Appalachian section of topography.	Not fixed.
Davis, C. D	Assistant geologist	....	Washington, D. C.
Gilbert, G. K	Geologist	Appalachian division of geology.	Washington, D. C.
Hague, Arnold	Geologist	Yellowstone Park division.	Mammoth Hot Springs, Wyo.
Hawkins, R. R	Geologist	California division of geology.	San Francisco, Cal.
Karl, Anton	Topographer	Northeastern section.	Washington, D. C.
Kerr, Mark B	Disbursing agent	Western division.	Not fixed.
Renshawe, John H	Geographer	Central section of topography	Not fixed.
Rogers, Alfred M	Disbursing agent	Rocky Mountain division.	Denver, Colo.
Taylor, A. O'D., jr	Special disbursing agent.	Division Archean geology.	Newport, R. I.

The fiscal system of the Survey was described at considerable length in the testimony of the Director before the joint

commission to inquire into the organization of certain scientific bureaus of the Government, published in 1886. All the blank forms used in it are there given.

THE CUSTODIAL SYSTEM.

PRINCIPLES OF THE SYSTEM.

The fundamental principles out of which the custodial system of the Survey has grown are related to those underlying the fiscal system. They are as follows: (1) Means should be adopted to prevent extravagance and reckless use of the property of the Survey; (2) every agent of the Survey should be required to account for all property in his custody; and (3) responsibility should not be merely documentary, but actual.

As already set forth, the chiefs of scientific divisions have every incentive to secure economical administration of the business affairs of their divisions; they are responsible for the property under their control and their subordinates are responsible to them. But, in order to fix definitely the responsibility for every article in the possession of the Survey, there is a class of agents, made up mainly of chiefs of division and their scientific assistants, who are designated "custodians of property" and who are charged with the custody of and are held responsible for all property owned by the Survey; and this class of agents is made so large that each individual may have personal knowledge of every article with which he s charged. In order to avoid dual responsibility on the part of the same individual in different rôles, the two classes of business officers—disbursing agents and custodians of property—are made up so far as practicable of different individuals.

METHODS EMPLOYED.

All property acquired by the Survey is placed in the hands of the custodians of property, who are held responsible therefor. The custodians incur responsibility through the certificates on the purchase vouchers, as already noted, and there is a system of records by which the responsibility is constantly fixed and by which accounts relating to all property in the possession of the Survey are kept in convenient form.

Property is classed as expendible and non-expendible. The first class comprises articles which are consumed (food and forage), quickly worn out in service (certain tools), or perishable (certain laboratory apparatus). The second class comprises articles which, with ordinary care, last for considerable periods. The various articles required in the prosecution of the work of the Survey have been classified under these two heads in the printed Regulations issued in 1882. The two classes are treated alike in the records, save in their ultimate disposition.

Both classes of Survey property are sometimes transferred from district to district and from one custodian to another. This is done by means of invoices and receipts, in which the property is so described that every article may be readily identified and which are numbered in definite series; and record of the transactions is entered in the returns of the custodians, and these returns are compared and verified quarterly by the property clerk, who has general oversight of custodial matters. When non-expendible property is transferred by an employee of the Survey who is not a custodian, a receipt therefor is taken and such employee becomes responsible to the custodian for the property.

As property is consumed, worn out, lost, or otherwise rendered unserviceable, it becomes necessary to make a record of the fact, and it is to facilitate this that the classification of property has been devised. When expendible property has been consumed or destroyed, the custodian to whom it is charged is authorized to drop it from his record, either with the simple statement that it has been expended or, if the expenditure is in any way unusual, with an explanation as to the manner in which it has been expended. But when non-expendible property is worn out or otherwise rendered unserviceable, the custodian reports the fact to the Director and requests to be relieved of responsibility; and the Director, after having satisfied himself of its propriety by personal inspection or by other means, grants the desired relief in writing. It sometimes happens that property (for example, animals and vehicles) becomes unsuitable for the purposes of the Survey and yet retains some value,

and statutory provision has been made for the condemnation and sale by auction of such property. It sometimes happens, too, that non-expendible property used in the field is lost or destroyed through accident, and provision is made for relieving the custodian of responsibility in such cases; but it is required that affidavit be made detailing the circumstances attending the loss or destruction of the property. Where non-expendible property is disposed of by any of these methods an explanatory statement is entered in the record of the custodian and transmitted by him to the property clerk, when the custodian's responsibility ceases.

CAMP EQUIPAGE AND RATIONS.

An important part of the work of the Survey is carried on in regions in which it is either inexpedient or impossible to find suitable lodgings and subsistence in hotels. Accordingly, provision is made for the purchase and use of camp equipage and rations; but the regulations governing the purchase of such property differ in principle from those relating to the acquisition of property used for other purposes. There are valid reasons for the distinction.

As already set forth, economy in the administration of the business affairs of the scientific divisions of the Survey is secured by the method of allotment, under which chiefs of division have the highest incentives to reduce expenses. Such officers are accordingly given large discretion in the purchase of the property required in their divisions. But camp life may be made either simple or very expensive; long experience is required to secure a frugal and successful management of a camp, and it cannot be assumed that the heads of all scientific parties and divisions have had such experience. In order, therefore, that the inexperienced may profit by the knowledge of others, lists of articles and rations required in camp life have been prepared with great care, and such lists, having been approved by the Secretary of the Interior, are promulgated for the guidance and use of camp parties. These lists comprise (1) a schedule of field supplies, including 46 articles; (2) a schedule of field material, including 35 articles; and (3) a ration list, including 29 articles.

Thus the chiefs of divisions and parties living in camp are subjected to certain special regulations relating to the acquisition of property required by their mode of life which do not apply under other circumstances; and by these regulations they are in a measure relieved of responsibility in making purchases, the Director assuming a limited responsibility in that the decision as to articles and amounts for the ration is made by him. But after such property is acquired it is held and accounted for in accordance with the principles and regulations of the custodial system.

An account of property is rendered quarterly by each custodian and is recorded in the office of the property clerk, and copies of all receipts and invoices for transferred property relating thereto are filed with it. In this account every article the acquisition of which is shown by a purchase voucher is entered upon the return of some custodian, and the entry is perpetuated from quarter to quarter until the article is finally disposed of. Thus the records of the property clerk tally with the records of the disbursing clerk. Every purchase is represented in the records of the latter by a purchase voucher and every article purchased is represented in the records of some custodian of property, whose signature appears in the voucher, and also of the property clerk, until some final disposition has been made of it. It will be seen that the custodian incurs responsibility either through the certificates upon purchase vouchers or through his receipts for property transferred to him, and that he is relieved of responsibility (1) by invoice of property transferred to and receipted for by other custodians, (2) by expenditure, (3) by written authority of the Director in the case of property abandoned, (4) by condemnation and sale of property at auction, or (5) by affidavit to the accidental loss of property. Complete documentary evidence is thus preserved of the custody and disposition of every article purchased by the Survey.

CUSTODIANS OF PROPERTY.

It has not been found expedient to assign employees of the Survey to exclusive duty as custodians of property.

The property clerk, who has general charge of the property in the possession of the Survey, is Mr. J. E. Allen; his work is performed under the supervision of the chief disbursing clerk. The other custodians of property, their official positions, the divisions and sections in which they are employed, and their headquarters are shown in the accompanying list:

Name.	Position.	Division or section.	Headquarters.
Bodfish, S. H	Topographer	Northeastern section of topography.	Not fixed.
Christie, P. H	Topographer	Appalachian section of topography.	Not fixed.
Gilbert, G. K	Geologist	Appalachian division of geology.	Washington, D. C.
Hague, Arnold	Geologist	Yellowstone Park division.	Mammoth Hot Springs, Wyo.
Hawkins, R. R	Geologist	California division	San Francisco, Cal.
Irving, R. D	Geologist	Lake Superior division.	Madison, Wis.
Karl, Anton	Topographer	Northeastern section of topography.	Washington, D. C.
Kerr, M. B	Disbursing agent.	Western section of topography.	Not fixed.
Maher, J. A	Topographer	Division of geography (general).	Washington, D. C.
Peale, A. C	Geologist	Montana division	Bozeman, Mont.
Renshawe, J. H	Geographer	Central section of topography.	Not fixed.
Rogers, A. M	Disbursing agent.	Rocky Mountain division.	Denver, Colo.
Taylor, A. O'D., jr	Special disbursing agent.	Archean division	Newport, R. I.
Thompson, A. H	Geographer	Western section of topography.	Not fixed.

It should be noted that the principles set forth and the methods described in the preceding paragraphs are applied with little modification to the property of more special character acquired or produced by the Survey in the departments of documents, library, museum, illustrations, stationery, &c., and the officers in charge of the divisions under which the work of these departments is performed are virtually custodians of the property under their charge.

The custodial system of the Survey was described at some length and the forms used were reproduced in the volume of testimony already mentioned.

THE MUSEUM SYSTEM.

PRODUCTION OF MUSEUM PROPERTY.

Although the building up of a museum is not a function of the Geological Survey, yet considerable collections of rocks, minerals, ores, fossils, &c. are made for purposes of necessary study in the prosecution of the work of the different divisions. Such materials are ultimately transferred to the United States National Museum, in accordance with the law providing that all collections made for the Government of the United States, when no longer needed for investigations in progress, shall be deposited there.

It should be observed that the collections made by institutions or individuals engaged in investigating the natural resources of a country are of unequal value. There are certain collections, embracing rare and beautiful minerals, the ores of the precious metals, &c., which possess intrinsic value and are readily marketable; and there are certain other materials, embracing well preserved fossils, typical rocks, ores, minerals, &c., for which there is a demand for educational and museum purposes. In recent years museums, both independent and connected with educational and scientific institutions, have greatly multiplied; there is a constant demand for museum material, and a trade in such material has sprung up. Thus there is a class of museum material which has money value, and it is desirable that a definite system of preserving and accounting for such property shall be followed. But there is another class of material collected by the investigator, comprising rocks, soils, some ores and minerals, and common or ill preserved fossils, destitute of money value, worthless in a museum, and useful only in elaborating the field notes of the geologist or paleontologist. It would be manifestly unwise to preserve such material in the National Museum, and it is accordingly destroyed. Since the collector is best

able to judge of the value of his own collection and will be very unlikely to underestimate it, provision is made for allowing each investigator to select from the material collected in the progress of his work that which shall be submitted for permanent preservation.

ACQUISITION, CUSTODY, AND TRANSFER OF COLLECTIONS.

The employees of the Survey are provided with printed label blanks, which are filled out and attached to specimens as collected in the field, and a field number is given to each specimen upon the label and in the note book of the collector.

Sometimes specimens are collected by persons not connected with the Survey and are transmitted either as gifts or with requests for identification or for more extended information. When it is believed that the public interest will be subserved thereby all such inquiries are answered as fully as seems to be desirable. If it is requested, the specimens are returned; but, if no such request is made, they are either destroyed or, if of sufficient value, labeled by the collaborator by whom they are examined, thus becoming Survey property and subject to the regulations controlling the collections made by its employees.

The material collected by the specialists employed upon the Survey is of exceedingly various value and character; the specific purposes for which it is employed are also various; and it is therefore inexpedient to prescribe regulations for the use and disposition of the material so long as it remains in the hands of the collector. Frequently there is no record of the material brought together by the collector, except in his own note books, lists, and catalogues, and he is not charged with it upon any of the general records of the Survey. If, however, the material in the possession of an employee has been acquired by gift through the Director or has been transferred to him by another officer of the Survey for examination, a record of his acquisition of the property is contained in the correspondence files of the Survey and he is held accountable for it Moreover, when collections are shipped at the expense of the Government, they become subjects of record and their custodians are accountable for them in a general way.

There are three ways in which collectors dispose of their acquisitions: First, if the material is worthless except for immediate study, it is preserved as long as may be required for that purpose and is then destroyed. In this case there is no account of the production and disposition of the material, except in the records of the collector and in the transportation records if it has been shipped as public property. Second, if the material is of value for museum purposes, if it promises to be useful in subsequent researches, or if for any other reason it is deemed wise to preserve it in the National Museum, it is transferred to that institution by one of the two methods described in a subsequent paragraph, and there is a record of such transfer both in the Geological Survey and in the National Museum. Third, if the maker of the collection is for any reason unable to investigate the material in the desired manner, it is transferred through the Director to some specialist, generally within but sometimes without the Survey, for the requisite examination, and the material thus becomes a subject of general record in the Survey. The person to whom the material is transferred, either from collectors or from outside parties, disposes of it after investigation in one of these ways.

There are two modes of transferring to the National Museum material collected in the progress of the work of the Survey: (1) Certain of the collaborators of the Survey are honorary curators of the National Museum and have charge in the Museum of the collections pertaining to subjects which they are studying as members of the Survey. When a collaborator has completed his investigation of a specimen or collection and has prepared, identified, and suitably labeled it, he formally transfers it to the National Museum through the accessions clerk of that institution and receives from him a museum number which is inscribed upon the label or labels. The material then becomes the property of the Museum and is arranged upon the shelves or in the drawers provided for the purpose. To facilitate such transfer, some of these collaborators keep in their offices parts of the catalogue of the Museum, upon which there is a duplicate record of the transfer. The principal rec-

ord of transfer is, however, that of the accessions clerk of the National Museum. (2) When a collaborator of the Survey who is not a curator of the National Museum desires to transfer specimens or collections to that institution, they are prepared, labeled, and packed, a suitable list or catalogue is added, and the whole is transferred to the Museum by means of a formal letter addressed to the Director and by him referred to the officers of the Museum. Material so transferred is unpacked, entered in the catalogue, numbered in the series, and arranged for preservation or exhibition in the Museum in accordance with the plans of that institution; and the principal record of the transfer, in which all such collections are credited to the Geological Survey, is kept by the accessions clerk of the Museum.

The following officers of the Survey are honorary curators of the National Museum:

Name.	Function.	Division.	Museum department.
W. H. Dall......	Paleontologist.	Cenozoic division of invertebrate paleontology.	IX. Mollusks.
C. D. Walcott...	Paleontologist.	Paleozoic division of invertebrate paleontology.	XII. A. Invertebrates.
C. A. White.....	Paleontologist.	Mesozoic division of invertebrate paleontology.	XII. B. Invertebrate fossils.
L. F. Ward	Paleontologist.	Fossil plants..........	XIII. A. Fossil plants. XIII. B. Recent plants.
F. W. Clarke....	Chemist.......	Chemistry and physics.	XIV. Minerals.

The work of the Survey is greatly facilitated by the cooperation existing between it and the National Museum.

THE ILLUSTRATION SYSTEM.

USES OF ILLUSTRATIONS.

With the increase of human knowledge there has been a constant growth of literature, until its volume has become enormous.

There is a distinction between what is known as pure literature and the literature of science. Pure literature deals with certain human emotions, passions, and qualities that are constant in character, but not reducible to terms of exact knowledge. The subjects of pure literature may therefore be treated with limited antecedent knowledge on the part of the author as to the manner in which the same and related subjects are treated by other authors. The classics of pure literature may be as old as the language, even as old as written history. But in scientific literature, which deals with subjects of exact knowledge, the writings of each period represent the existing sum of human knowledge concerning each of the subjects treated, and, combined, define the intellectual plane of the period and form the basis for further progress. In science each investigator commences where his predecessor left off, and the growth of scientific knowledge is thus a process of evolution commencing at fixed points, each determined by antecedent knowledge. So the classics in science are always modern and the standard scientific treatises of past decades and generations have little more than historic value.

The original investigator is therefore compelled to read a voluminous current literature in order to keep abreast of advanced scientific thought. Keeping pace with the literature of his subject is indeed one of the most arduous duties of the scientific student. It is from this cause more than any other that the modern specialization of scientific work has become necessary. Moreover, the great cost of the publications which it is necessary for the investigator to consult is an additional burden upon the scientific man and upon scientific institutions. Every device for diminishing the volume of scientific literature without reducing the sum of knowledge contained therein is therefore a boon to the student, and in the Geological Survey much thought has been given to plans for securing this end.

One of the most satisfactory methods for diminishing the volume of scientific treatises on general or special subjects is that of substituting graphic representation for verbal statement. A map occupying a page not only embodies information which

it would require a score of pages of text to convey verbally, but presents the information in a more complete and intelligible form; and a landscape sketch, in which the elements of the landscape are of geologic significance and which may be printed on a single page, may tell eloquently what could be told but imperfectly in an entire chapter. So there is great economy to the reader in the use of graphic illustrations wherever practicable, and within certain limits there is economy to the publisher in substituting graphic representation for verbal statement.

The graphic representation of phenomena has another important advantage, which is not often realized. In certain investigations, involving study of the relations of parts, graphic representation is essential to the comprehension of relation. In regions of complex geologic structure, for example, the student may be unable to perceive the relations between different outcrops of similar deposits, and may be unable to determine whether all represent a single stratum of irregular form or a number of distinct strata until the observations are projected upon paper in both horizontal and vertical planes. So the graphic method becomes an instrument of research as well as a means of representing the results of research.

The uses of photography have multiplied with the development of the art until they have become innumerable. Photography is employed in the Geological Survey in many ways. It is employed for the reproduction of landscapes, for the use of both the geologist and the topographer, and for reproducing exposures of rocks for the geologist. The unique and instructive scenery of the mountains and plateaus of the West, the historic hills and valleys of the Appalachian region, and the peculiar features of the Mississippi Valley plains are all successfully reproduced by means of photography. The complex and puzzling features of the glacial drift, the structure of granites, limestones, ore beds, &c., and the relations of the members in sections of displaced and convoluted beds in mountain regions are all satisfactorily represented by the same process.

Photography is also used largely in the preparation of drawings of fossil plants, animals, &c., by a method which has been devised within the Survey. The object is photographed upon specially prepared paper; upon the photograph a drawing is made in indelible ink, by an artist who has the object before him, in such way as to represent the characteristics of the object in a more satisfactory manner than can be done by photography alone; and the photographic impression is then bleached out, leaving a drawing in ink which can be readily and cheaply reproduced.

Photography is also largely used in the Survey for the reproduction of maps. Certain maps required for extended use are rare and a single copy only is obtainable. This is cheaply multiplied by photography. The scales of maps required for use in the field or as copy for the lithographer in the preparation of illustrations for reports are sometimes unsuitable; by photography these maps are quickly reproduced upon the desired scale at small cost. The maps drawn in the geographic department and certain other drawings prepared in the office of the Survey are elaborate and finely executed, and their loss or injury would be serious; and such maps or drawings are generally duplicated by photography.

Classified by the general purposes for which they are used, the illustrations produced by the Survey belong to two categories. The first embraces illustrations needed in the prosecution of Survey work, e. g., field sketches and photographs used in the preparation of topographic maps or in the prosecution of geologic studies, bleachable photographs of fossils and crystals, photographs of maps for working purposes, &c. The second category includes illustrations to be engraved for reports on special subjects published by the Survey. Photographs and sketches are not published independently nor distributed as publications of the Survey; but in some cases such illustrations are exchanged with correspondents of the Survey, just as minerals, fossils, &c. are sometimes exchanged, and provision is made for keeping a record of such exchanges under the document system.

PRODUCTION, CUSTODY, AND DISPOSITION OF ILLUSTRATIONS.

The illustrations produced by the Survey fall into five classes, namely: (1) maps, (2) field sketches, (3) field photographs, (4) photographs made in the office from objects collected in the field or otherwise acquired, and (5) finished drawings.

(1) The maps prepared by the Survey comprise the atlas sheets, which have been described in detail in previous reports, and such special maps as are required from time to time for the illustration of reports. The atlas sheets result from the operations of the geographic division. In general each topographer is charged with the survey of a stated area during each field season and with the construction of a map covering that area during the succeeding office season. The topographers are thus their own draftsmen; but it is sometimes expedient to assist the topographer in this part of his work, and for this reason a section of drafting has been established in the geographic division. In addition to such work as may be required upon the atlas sheets, the drawing of the special maps required for the reports is performed in this section.

The manuscript atlas sheets are transmitted from the geographic division, through the Director, to the Public Printer for engraving under contract, the proofs are returned through the same channel and are revised in the geographic division, and the copies of the printed sheets required for the current use of the Survey are purchased and placed in charge of the division of geography.

The assignment of a topographer for the survey of an area is a matter of record. By means of the custodial and stationery systems, account is kept of all material that passes into his hands, and when the manuscript map which represents the outcome of his work is completed his account may be balanced and the exact cost of the survey and drawing computed. The finished map is transferred to the chief geographer and becomes a definite unit of property, of which strict account is kept at every stage, as drawing, proofs, and, finally, printed maps and engraved plates. Moreover, each map bears the name of the topographer who made the survey and executed

or directed the drawing. Thus the responsibility for the work as well as for the materials is definitely and permanently fixed.

(2) Field sketches are made by the geologists and topographers of the Survey in the progress of their work. Like the collections, they fall into two classes, the first of which is of only temporary and the second of permanent use; and, as in the case of collections again, the disposition of field sketches is determined by their producer. The field sketches of the topographers are used in the construction of the maps, but no further use is made of them and they do not become subjects of record except in the note books of the topographers. A large portion of the sketches made by the geologist in the field are only of service in correlating observations and forming conceptions concerning the relation of the rock masses and other geologic phenomena investigated; and no account is kept of such illustrations except in note books. But a portion of the sketches made by the geologist in the field, as well as most of the drawings made by him in the office, are useful in illustrating the report upon his work; and all such sketches are so elaborated as to serve as copy for the engraver or lithographer, either by the geologist himself or by artists employed for that purpose in the illustration division of the Survey. Such sketches become matters of record when they are transferred to the illustration division for reconstruction or to the editorial division for transmission to the Public Printer for reproduction.

(3) Field photographs are generally taken either by the geologists or topographers themselves or by photographers in the regular employ of the Survey; but in certain special cases local photographers are employed in the field. Most of the geologic divisions of the Survey are provided with cameras, and a number of the geologists have become skilled in their use and make their own negatives. This is advantageous when the field of work is remote and but a limited number of negatives is required; but, when the field is readily accessible and the number of negatives required is large, it is more economical to have the work done by skilled photographers employed regularly for the purpose.

The photographs taken by the Survey become public property, and record is kept both of the negatives and of the prints made therefrom. When photographs are made by local photographers under special contract, however, the negatives may or may not become the property of the Government, according to the terms of the contract; but record is made of the prints as soon as they reach the illustration or editorial division. A large proportion of the photographs taken by the geologists in the field and nearly all of those taken by the topographers are only of temporary use, and after they have served their purpose the negatives are destroyed. A smaller proportion are of permanent value and are ultimately either worked up into finished drawings or reproduced directly by wood engraving or otherwise for the illustration of reports, the negatives being preserved as long as necessary.

(4) The chief purposes of the photographs made in the office have already been indicated. They are made upon requisition countersigned by the chief clerk or upon specific authorization of the Director, and when delivered the receipt of the photographs is acknowledged upon the requisition blank by the person for whom they were made. There is thus a definite system of regulating and controlling this class of work in the photographic laboratory. The negatives are preserved whenever necessary.

(5) There is a small corps of artists employed in the preparation of finished drawings designed for the illustration of reports. These drawings represent landscapes, rock exposures, geologic sections, various kinds of diagrams, crystalline and other mineral forms, microscopic slides, fossil remains of animals and plants, &c. They are constructed from field sketches and photographs, from data furnished by the authors of reports, or from the objects themselves. Their production is specifically authorized by the Director, either orally, when they are prepared in advance of the completion of the reports for publication, or through the editorial division, when the reports which they are designed to illustrate have been accepted for publication. A record of the finished drawings produced is kept in the division of illustrations.

The proofs of illustrations are revised, and the original drawings and duplicate proofs are preserved and recorded, in the illustration division.

The most delicate and important duty connected with the preparation of finished drawings for the illustration of reports is the selection of methods of reproduction; for, while in certain cases the most advantageous method may be evident, there are other cases in which different methods might be employed and in which the question of cost becomes an important element in the selection. Certain general principles, which have been set forth in previous reports, govern the selection in some cases: e. g., lithography is never employed when it can be avoided, partly because lithographs are expensive both in reproduction and in printing, and partly because it is not practicable to preserve them and duplicate the illustrations in different arrangements when occasion requires; and wood engravings and modern photo-process engravings, which are not open to these objections, are used as far as possible. But there are many cases in which lithography would produce the best results, wood engraving somewhat inferior results, and photo-process engraving still less satisfactory results; and the question to be decided therefore involves the careful weighing of the antagonistic considerations of excellence and cheapness. The question is further complicated by the manner in which the contracts for reproduction are ordinarily made, the contracts for lithography commonly including printing, while those for wood processes do not; and, since it frequently happens that photographs or other subjects which might be reproduced directly on stone or wood must be redrawn in order that they may be reproduced by the photo processes, the cost of drawing may have to be considered also.

Every effort is made to reduce the cost of illustrations for reports of the Survey to as low a figure as is consistent with a high standard of excellence, and it is accordingly necessary to exercise judgment as to the best methods of reproduction of illustrations in connection with nearly every publication issued by the Survey. It is believed that these efforts have been eminently successful, since the illustrations of the publications of

the Geological Survey compare favorably with those of other scientific institutions, both at home and abroad, while the cost of reproduction of such illustrations has been reduced fully 60 per cent. since the Survey was established.

The division of illustrations is in charge of Mr. W. H. Holmes, who employs a number of assistants upon finished drawings and the proof-reading of engravings; and the photographic laboratory belonging to the division is in charge of Mr. J. K. Hillers, who has four skilled assistants. This force does not include that employed in the section of topographic drawing in the division of geography.

THE EDITORIAL SYSTEM.

FUNCTIONS OF THE EDITORIAL DIVISION.

As provided in the organic law of the Survey its publications consist of four classes, namely: (1) Annual reports, (2) monographs, (3) bulletins, and (4) statistical papers. These publications reach a considerable volume annually. During the fiscal year covered by this report there have been published two bound volumes in octavo, three in quarto, and thirteen unbound bulletins, aggregating 4,253 pages of text illustrated by 350 plates and 327 figures.

The labor involved in supervising so large an amount of publication as that indicated, comprising the suitable preparation of manuscript for the press and the careful and repeated proof-reading demanded by the highly technical character of the work, has necessitated the development of an editorial system.

The principal considerations borne in mind in the development of this system are the following: (1) Individuals engaged in researches involved in or collateral to the extension of the geologic survey of the United States over the national domain should have facilities for publication of the results of their work equal to those afforded by the publishing houses or public institutions of this or other countries; (2) no matter should be published unless it be of sufficient value to warrant publication and extended distribution; (3) the publications of

the Survey should be prepared, printed, and bound on a uniform and consistent plan for each of the classes established by law; (4) corrections and alterations should be made as far as practicable in the manuscript rather than in the proof, proof corrections being expensive; and (5) the author, who may be engaged in investigations or other important work of high grade, should be relieved as far as practicable of the details of book making, which may be satisfactorily performed by others.

Under the second head it may be remarked that it is to avoid the risk of burdening the series of Survey publications with trivial matter, statements or theories of doubtful validity, and all writings whose value to the people of the country is not commensurate with the cost of publication, that the papers offered for publication by the Survey are so searchingly criticised by the Director and his collaborators in the manner hereinafter set forth. Moreover, should it appear necessary at any time, matter offered to the Survey for publication, either by its own officers or by others, would be submitted to competent authorities outside of the institution for a statement as to its scientific value and for an opinion as to the desirability of publishing it.

The consideration referred to under the fifth head involves one of the fundamental principles of the policy of the Survey, i. e., the division of labor in such manner that each employee shall be assigned to those duties only which he can most advantageously and economically perform. In a simple organization employing few individuals this principle may be ignored without serious loss, but in a complex organization performing various functions and employing a large number of individuals differentiation of function is believed to be essential to the highest efficiency.

There is another and important object in maintaining the editorial division, i. e., that of securing to the authors of the reports issued by the institution the advantages of literary criticism in advance of publication. Moreover, the employment of an editor, one of whose chief duties is to assist the Director in supervising the publications of the Survey, enables the latter to make his supervision much closer and more detailed

than would otherwise be possible with so large a literary product.

METHODS OF WORK.

Nearly all the reports published by the Survey are prepared either by chiefs of division or by assistants working under their direction. A few reports prepared by geologists of the country not in the employ of the Survey are published; but these relate to subjects upon which the Survey is engaged, and contain information of value to the Survey which could not be so economically acquired in any other way.

The reports prepared by chiefs of division are submitted to the Director for approval and are generally discussed at length by the author and Director and sometimes by other officers of the Survey before they are transferred to the editorial department. Reports prepared by assistants are examined by chiefs of division and if approved by these officers are transmitted to the Director and discussed in the same manner as the reports emanating from the chiefs themselves. Reports prepared either by geologists not connected with the Survey or by assistants whose chiefs are not specialists in the subjects treated are transmitted to the Director and generally submitted by him to some member or members of the Survey especially familiar with the subject reported on, and if the reports are approved by them they are submitted to the Director anew with either oral or written recommendation for publication. After approval by the Director, all manuscripts prepared for publication are transmitted to the editorial division with instructions as to the class of publications in which they are to appear.

One of the principal functions of the editor is to maintain uniformity in the different classes of publications and to make such rearrangements of and additions to the manuscript as may be required for that purpose. In the interests of convenience on the part of readers it is desirable that books shall be properly arranged under chapters, sections, and other divisions and that all such divisions shall be suitably indicated by means of titles. It is desirable also that a list of the chapters, sections, or other divisions in each volume, so arranged as to give a log-

ical view of the contents of the treatise, shall be introduced in the work. Moreover, the value of books to most users is greatly increased by the addition of an index. Accordingly the publications of the Survey are provided with complete lists of contents and of illustrations and full indexes.

When a manuscript work reaches the editor it is supplied with title pages and with lists of contents and illustrations if these are needed. The manuscript is then critically read, clerical errors are corrected, obviously necessary transpositions and other purely literary corrections are made, quotations and bibliographic references are verified and the latter are reduced to a uniform plan, and references to the illustrations are made or corrected. Where more important alterations appear to be required they are suggested to the author (and in some cases to the Director), and if the number of alterations is large the manuscript is returned to the author for revision. In some cases this critical examination leads to the rejection of a paper.

The manuscript is next prepared for the printer: the type, size and style of headings, &c. are indicated and all necessary instructions for printing are given. Meantime the illustrations are transferred to the division of illustrations for editing, for redrawing when required, and for such directions as to reproduction as may be deemed necessary. The manuscript and illustrations are then transmitted to the Public Printer by the Director.

Duplicate galley proofs are returned from the Government Printing Office to the editor: one set is first corrected by the manuscript and then submitted to a critical reading, similar to that given to the matter in manuscript, and the necessary corrections and changes are made; and the other set is transmitted to the author for his revision, and finally his corrections are transferred to the galley in the hands of the editor, which is then returned to the Printing Office.

The page proof is in like manner conveyed to the editorial division and is there read and revised and running titles and signature marks are added, the page proof being in some cases also sent to the author for revision.

A "second page revise," as it is technically called, is also furnished to the editor. An index is then prepared, or, if one has been prepared by the author, it is revised and corrected if necessary. After the second page revise has received the final corrections (in rare cases a third or fourth revise may be required) it is transmitted to the office of the Public Printer as approved and passes out of the custody of the editorial division.

A set of each proof, both galley and page, is preserved in the office of the editor, and the custody of the text and illustrations is suitably recorded at every stage, from the time they reach the Director's hands until they are finally transmitted to the Public Printer as approved.

The proofs of illustrations are revised by the chief of the division of illustrations and by authors in accordance with his direction.

The editorial work of the Survey is in charge of Mr. Thomas Hampson, who has eight assistants; but the general correspondence of the office is also conducted in this division and occupies most of the time of several of these assistants.

THE DOCUMENT SYSTEM.

PUBLICATIONS OF THE SURVEY.

The annual reports of the Survey are issued in four editions. The first edition comprises the usual number of documents ordered by Congress, or 1,900 copies; the second is a special congressional edition of 3,000 copies, of which 1,000 are for the use of the Senate and 2,000 for the use of the House; the third is printed to accompany and form the third volume of the annual report of the Secretary of the Interior, of which 750 copies are issued; and the fourth is an edition of variable number published under a joint resolution of each Congress, of which a part is designed for the use of the Senate and House of Representatives and a part for the use of the Geological Survey. Of the second and third annual reports, 2,500 copies each, and of the fourth and fifth annual reports 5,000 copies each, were printed for the use of the Survey, and of the sixth and seventh 5,000 copies each are authorized.

The monographs, bulletins, and statistical papers are issued in two editions, the first comprising the usual number of documents ordered by Congress and the second the edition of 3,000 copies provided for sale and exchange through the Geological Survey, in accordance with the provisions of the law regulating its publications. Only the latter edition passes into the custody of the Survey.

Small special editions of each of the statistical papers and of two bulletins on subjects believed to be of wide interest have also been provided for the use of the Survey by order of the Secretary of the Interior.

In the accompanying tables the publications which have passed into the custody of the Survey are enumerated, and the size of edition, the cost per copy as determined by the Public Printer (except in the case of annual reports, the cost of which is estimated), the aggregate number of volumes, and the total cost are also exhibited. From these tables it will be seen that under the present directorship of the Survey there have been issued 5 annual reports, 10 monographs, 39 bulletins, and 3 volumes of statistical papers; in all, 57 distinct publications, in editions ranging from 2,500 to 5,000. It will also be seen that the aggregate value of the property in the form of publications for which the Survey has incurred responsibility during the last five years is no less than $159,390.

TABLE 1.—*Annual reports.*

Title.	Edition.	Estimated average cost per volume.	Total cost.
Second	2,500	$2 00	$5,000
Third	2,500		5,000
Fourth	5,000		10,000
Fifth	5,000		10,000
Sixth	5,000		10,000
Total	20,000		40,000

TABLE 2.—*Monographs.*

Title.	Edition.	Price per copy.	Total cost.
II. Tertiary History of the Grand Cañon District, by Clarence E. Dutton.	3,000	$10 12	$30,360
III. Geology of the Comstock Lode and the Washoe District, by George F. Becker.	3,000	11 00	33,000
IV. Comstock Mining and Miners, by Eliot Lord.	3,000	1 50	4,500
V. The Copper-Bearing Rocks of Lake Superior, by R. D. Irving.	3,000	1 85	5,550
VI. Contributions to the Knowledge of the Older Mesozoic Flora of Virginia, by W. M. Fontaine.	3,000	1 05	3,150
VII. Silver-Lead Deposits of Eureka, Nevada, by Joseph S. Curtis.	3,000	1 20	3,600
VIII. Paleontology of the Eureka District, by Charles D. Walcott.	3,000	1 10	3,300
IX. Brachiopoda and Lamellibranchiata of the Raritan Clays and Greensand Marls of New Jersey, by Robert P. Whitfield.	3,000	1 15	3,450
X. Dinocerata: A Monograph of an Extinct Order of Gigantic Mammals, by O. C. Marsh.	3,000	2 70	8,100
XI. Geological History of Lake Lahontan, a Quaternary Lake of Northwestern Nevada, by I. C. Russell.	3,000	1 75	5,250
XII. Geology and Mining Industry of Leadville, Colorado, with atlas, by S. F. Emmons.	3,000	8 40	25,200
Total	33,000	....	125,460

TABLE 3.—*Bulletins.*

Title.	Edition.	Price per copy.	Total cost.
1. On Hypersthene-Andesite and on Triclinic Pyroxene in Augitic Rocks, by Whitman Cross; with a Geological Sketch of Buffalo Peaks, Colorado, by S. F. Emmons.	3,000	$0 10	$300
2. Gold and Silver Conversion Tables, by Albert Williams, jr.	3,000	5	150
3. On the Fossil Faunas of the Upper Devonian along the Meridian of 76° 30′ from Tompkins County, N. Y., to Bradford County, Pa., by Henry S. Williams.	3,000	5	150

TABLE 3.—*Bulletins*—Continued.

Title.	Edition.	Price per copy.	Total cost.
4. On Mesozoic Fossils, by Charles A. White...	3,000	$0 05	$150
5. A Dictionary of Altitudes in the United States, by Henry Gannett.	3,000	20	600
6. Elevations in the Dominion of Canada, by J. W. Spencer.	3,000	5	150
7. Mapoteca Geologica Americana: A Catalogue of Geological Maps of America (North and South), 1752–1881, by Jules Marcou and John Belknap Marcou.	3,000	10	300
8. On Secondary Enlargements of Mineral Fragments in Certain Rocks, by R. D. Irving and C. R. Van Hise.	3,000	10	300
9. A Report of Work done in the Washington Laboratory during the Fiscal Year 1883–'84.	3,000	5	150
10. On the Cambrian Faunas of North America, by Charles D. Walcott.	3,000	5	150
11. On the Quaternary and Recent Mollusca of the Great Basin, by R. Ellsworth Call. Introduced by a Sketch of the Quaternary Lakes of the Great Basin, by G. K. Gilbert.	3,000	5	150
12. A Crystallographic Study of the Thinolite of Lake Lahontan, by Edward S. Dana.	3,000	5	150
13. Boundaries of the United States and of the Several States and Territories, with a Historical Sketch of the Territorial Changes, by Henry Gannett.	3,000	10	300
14. The Electrical and Magnetic Properties of the Iron Carburets, by Carl Barus and Vincent Strouhal.	3,000	15	450
15. On the Mesozoic and Cenozoic Paleontology of California, by Charles A. White.	3,000	5	150
16. On the Higher Devonian Faunas of Ontario County, New York, by John M. Clarke.	3,000	5	150
17. On the Development of Crystallization in the Igneous Rocks of Washoe, Nevada, by Arnold Hague and Joseph P. Iddings.	3,000	5	150
18. On Marine Eocene, Fresh Water Miocene, and other Fossil Mollusca of Western North America, by Charles A. White.	3,000	5	150
19. Notes on the Stratigraphy of California, by George F. Becker.	3,000	5	150

TABLE 3.—*Bulletins* — Continued.

Title.	Edition.	Price per copy.	Total cost.
20. Contributions to the Mineralogy of the Rocky Mountains, by Whitman Cross and W. F. Hillebrand.	3,000	$0 10	$300
21. The Lignites of the Great Sioux Reservation, by Bailey Willis.	3,000	5	150
22. On New Cretaceous Fossils from California, by Charles A. White.	3,000	5	150
23. Observations on the Junction between the Eastern Sandstone and the Keweenaw Series on Keweenaw Point, Lake Superior, by R. D. Irving and T. C. Chamberlin.	3,000	15	450
24. List of Marine Mollusca, by W. H. Dall	3,000	25	750
25. The Present Technical Condition of the Steel Industry of the United States, by Phineas Barnes.	3,000	10	300
26. Copper Smelting, by Henry M. Howe	3,000	10	300
27. Report of Work done in the Division of Chemistry and Physics mainly during 1884–'85.	3,000	10	300
28. The Gabbros and Associated Hornblende Rocks occurring in the Neighborhood of Baltimore, Md., by George H. Williams.	3,000	10	300
29. On the Fresh-Water Invertebrates of the North American Jurassic, by Charles A. White.	3,000	5	150
30. Second Contribution to the Studies on the Cambrian Faunas of North America, by Charles D. Walcott.	3,000	25	750
31. Systematic Review of our Present Knowledge of Fossil Insects, including Myriapods and Arachnids, by Samuel H. Scudder.	3,000	15	450
32. Lists and Analyses of the Mineral Springs of the United States, by Albert C. Peale.	3,000	20	600
33. Notes on the Geology of Northern California, by J. S. Diller.	3,000	5	150
34. On the Relation of the Laramie Molluscan Fauna to That of the Succeeding Fresh-Water Eocene and Other Groups, by Charles A. White.	3,000	10	300
35. Physical Properties of the Iron-Carburets, by Carl Barus and Vincent Strouhal.	3,000	10	300
36. Subsidence of Fine Solid Particles in Liquids, by Carl Barus.	3,000	10	300

TABLE 3.—*Bulletins*—Continued.

Title.	Edition.	Price per copy.	Total cost.
37. Types of the Laramie Flora, by Lester F. Ward.	3,000	$0 25	$750
38. Peridotite of Elliott County, Kentucky, by J. S. Diller.	3,000	5	150
39. The Upper Beaches and Deltas of the Glacial Lake Agassiz, by Warren Upham.	3,000	10	300
Total	117,000	....	11,400

TABLE 4.—*Statistical papers.*

Title.	Edition.	Price per copy.	Total cost.
Mineral Resources of the United States, 1882.....	3,000	$0 50	$1,500
Mineral Resources of the United States, 1883 and 1884.	3,000	60	1,800
Mineral Resources of the United States, 1885	3,000	40	1,200
Total	9,000	....	4,500

TABLE 5.—*Special editions of statistical papers and bulletins.*

Title.	Edition.	Price per copy.	Total cost.
Mineral Resources of the United States, 1882.....	2,000	$0 50	$1,000
Mineral Resources of the United States, 1883 and 1884.	2,000	60	1,200
Mineral Resources of the United States, 1885......	2,000	40	800
Bulletin No. 5. A Dictionary of Altitudes of the United States, compiled by Henry Gannett.	500	20	100
Bulletin No. 32. Mineral Springs of the United States, by A. C. Peale.	500	20	100
Total	7,000	....	3,200

TABLE 6.—*Recapitulation.*

Series.	Aggregate number of volumes.	Aggregate cost.
Annual reports	20,000	$40,000
Monographs	30,000	100,290
Bulletins	117,000	11,400
Statistical papers	9,000	4,500
Special editions	7,000	3,200
Total	183,000	159,390

By reason of the great responsibility thus incurred by the Geological Survey, it has been deemed necessary to develop a comprehensive yet simple method of regulating the custody of this property and of accounting for it in accordance with the principles of the custodial system already explained.

PRINCIPLES RECOGNIZED IN THE DOCUMENT SYSTEM.

Among the considerations upon which the document system has been founded are the following: (1) All matter published by the Survey shall be issued in sufficiently large editions to meet present requirements and to remain accessible for a considerable term of years to all important libraries and to students interested in the subjects treated; (2) the method of distribution shall be such as to insure the reception of the publications by public libraries, scientific and educational institutions, and individuals engaged in special investigations of related subjects; and (3) the cost of publication shall be reduced to a minimum.

(1) The question as to the size of the editions of Survey publications required to meet the wants of the people was carefully considered by the framers of the law controlling their disposition, and the edition decided upon appears adequate to meet all demands, at least for the present.

(2) It should be borne in mind that the best method of distributing the publications of the Government depends upon their character; for the method which is best for one class of publications may not be the best for another class.

A large proportion of the publications of the Government are of general interest to the people, and it is desirable that they shall be widely and promptly distributed; and a method of distributing such publications gratuitously, through Congress and through certain Departments, has been adopted and has been found by experience to be at least measurably satisfactory. But with governmental endowment of special research in different lines—in anthropology and ethnology, in geography and geology, in geodesy, in the condition and changes of the coast, in sanitation and the public health, in the various branches of zoölogy, in fish and fisheries, in agriculture, in chemistry, in entomology, in climate and weather prognostication, in veterinary science and the health of animals, in astronomy, &c.—there has grown up a special class of publications which, while of great value and interest to the people of the country, are each of interest to only a limited number of them; and it has been found by experience that the ordinary regulations for the distribution of public documents are unsatisfactory for these special publications. In the first place, while the officers intrusted with the distribution of documents may be supplied with the addresses of the recipients of public documents generally throughout the country and may be able to extend their lists by means of applications and recommendations, they have not the addresses of the special students of the country to whom the documents would be of the greatest value; and accordingly students frequently fail not only to receive but even to learn of the existence of such documents. Again, excessive editions of special reports are sometimes published and the surplus remaining in the document rooms of Congress and of the governmental departments becomes a burden; and scandal has resulted from the means adopted for the relief of this burden and unwarranted reflections have thereby been cast upon the special publications of the Government. On the other hand, the editions published have in some cases been too small, and therefore inadequate to supply the needs of the libraries, the scientific and educational institutions, and the students of the country; the documents have consequently come to command high prices in second hand book

stores; and an undue burden is thereby imposed upon the individuals and institutions to whom the publications are necessary. So in various ways the general and gratuitous distribution of the special reports of the Government has been found by experience to be unsatisfactory.

It should be borne in mind, too, that the special publications of any government are of interest not only to the citizens of that government, but also to those of other nations. Science is cosmopolitan, and, in order that the best progress shall be made and that each country shall enjoy the benefits resulting from scientific investigations in other countries, it is necessary that there shall be international circulation of documents in which the results of research are recorded. The publications of the leading scientific, literary, and educational institutions and individuals of Europe, Asia, and Australasia, whether issued under governmental auspices or not, are in the leading public libraries and in many of the private libraries of this country, and constant use is made of them by the agents of our Government employed in special investigations; international associations and congresses of astronomers, geographers, and geologists and of members of medical and other professions have been organized during recent years, and much benefit has resulted therefrom to American participants; and it is eminently desirable, in the interest of international comity and harmony, as well as of scientific progress, that the special publications of this country relating to subjects of common interest throughout the globe should be properly distributed abroad. Much thought has consequently been devoted to the development of a system of international exchanges which shall permit of the prompt distribution of the publications of the Survey among the leading foreign institutions of learning and shall secure from them such of their publications as are useful to the Geological Survey.

The objections to the plan of general gratuitous distribution of documents embodying the results of special researches appear to be wisely met in the law regulating the disposition of the publications of the Geological Survey by sale and exchange, and the legislation upon this subject is therefore welcomed by

the people of the country who are interested in the progress of research.

(3) Economy in publication is secured in the Geological Survey, first, by reducing the cost of editorial work and printing to a minimum; second, by substituting graphic illustrations for verbal statement wherever economically practicable; and, third, by diminishing the cost of illustrations so far as is consistent with excellence, as has been set forth in preceding pages.

CUSTODY AND MODE OF DISTRIBUTION OF DOCUMENTS.

The custody of the documents distributed through the Survey is vested in the librarian. They fall into three classes, in which responsibility is incurred differently, viz: first, the regular editions of the monographs, bulletins, and statistical papers provided for by law and that part of the edition of the annual reports provided for in joint resolution which is specifically designed for the use of the Survey; second, certain small special editions of some of the publications of the Survey which are printed under the authority of the Secretary of the Interior for gratuitous distribution; and, third, the small number of photographs used for purposes of exchange. The first of these classes of documents is transferred to the office of the Survey from the Government Printing Office in lots, each accompanied by a receipt filled out with the name of publication, the style of binding, and the number of volumes, and after verification of the entries this receipt is signed by the librarian and a record of the transaction is made in a book kept for that purpose. The publications of the second class are received in a similar manner from the document clerk of the Interior Department and a similar record of the transaction is made, the receipt for each lot being returned to the Interior Department The photographs are printed in the laboratory of the Survey upon requisition of the librarian, countersigned by the chief clerk, and are receipted for by the librarian upon delivery.

Classified by the method of distribution, the documents are (1) those disposed of only by sale or exchange, including the monographs, bulletins, and statistical papers; (2) those disposed of either by regular exchange or gratuitous distribu-

tion, including annual reports and the small special editions of statistical papers and bulletins already mentioned; and (3) those disposed of by special exchange or distribution, including annual reports, the special editions, photographs, &c. The methods of accounting in the three cases are somewhat different:

(1) A ledger account is opened with each of the first of these categories of documents, in which the custodian is charged with the various lots received from the Public Printer and credited with the sales and exchanges as made. This ledger account thus shows the status of the editions of each document at any time. It is balanced quarterly, and an account of the sales, with the receipts therefrom, is transmitted to the United States Treasury through the disbursing officer.

The methods pursued in the making and recording of sales and in the making and recording of exchanges differ somewhat. When sales are made the orders and remittances are immediately entered in a day book, and when the document is transmitted this account, with the full address of the purchaser, is transferred to the ledger, and the entire correspondence, including the acknowledgment of receipt, is preserved. There is thus a triple record of the transaction: first in the day book, second in the ledger, and third in the correspondence files.

The method of accounting for exchanges is more elaborate and the records are kept in a different manner. The system of exchanges is based upon a list of scientific institutions and individuals, both foreign and domestic, which was carefully prepared soon after the organization of the Survey, with the view not only of placing the publications of the Survey in the best hands, but also of securing the greatest amount of material required in the library. To insure accuracy and completeness the list was subsequently revised by a commission of geologists appointed for the purpose, and it was finally referred to and approved by the Secretary of the Interior. The exchange list thus prepared is cautiously extended as circumstances require by the addition of the addresses of new libraries and institutions issuing publications of value to the Survey and the names of specialists who definitely express a desire to

make an exchange with the Survey and specify the material they propose to transmit; when, if the proposal seems fair, the addition of the address is authorized. The addresses are constantly revised and corrected.

The exchange list is printed upon galley slips, which are perforated in order that they may be easily divided into separate address labels, each of which bears a number used in keeping account of sending and return. The use of printed address slips instead of written addresses not only economizes time, but greatly diminishes the liability to error.

In addition to the ledger account with each publication, in which both sales and exchanges are entered, there is also assigned to each a check list, in which are printed numbers corresponding to those borne upon the different slips of the exchange list. The first use made of this check list is in controlling the transmission of the documents and of the accompanying letters of advice: Checks indicating transmission are first made upon the list by the proper authority; the list is next used as a guide in attaching the printed slips to the parcels in the shipping room; it is then used in filling out and mailing the accompanying letters; it is used once more in the verification of the work of addressing the parcels and preparing the letters when the matter is ready for transmission; and it is finally used for recording, by means of suitable checks, the acknowledgments of receipt. The check list is thus a permanent record of, first, the transmission of the document and, second, the receipt thereof by the person addressed.

The check list is supplemented by a series of charge cards, which are used also in the transmission of the documents distributed gratuitously. These cards are arranged, first, in groups or fascicles, in which the cards are of different colors, each assigned to a certain series of documents, while each card bears an address taken from the exchange list, together with its serial number, and the groups themselves are arranged alphabetically under the addresses. Each card is divided into a number of rectangles, and each rectangle has printed within it a number or abbreviation referring to one of the documents

of the series represented by its color; and there is space in the rectangle for recording the transmission of the document.

The system of recording thus triplicated is still further supplemented by the preservation of the receipts signed by correspondents.

There are accordingly four distinct records of the disposition of documents exchanged by the Survey: first, in the ledger account with each document; second, in the check list; third, in the charge card; and, fourth, in the receipt returned. These records are kept by different individuals and check one another so completely that there is scarcely a possibility of error.

(2) The method of accounting for the second category of publications—i. e., the regular exchanges, which are not sold, including annual reports and the small special editions already noticed—is identical with that followed in the case of the first, except that ledger accounts are not kept with the editions.

(3) The mode of accounting for the documents distributed gratuitously or by special exchange is somewhat different. Instead of an exchange list there is a list of correspondents, which is not printed, but kept in manuscript by means of the card system already described. A group of cards as large as may be required for each correspondent who has ever received a document issued by the Survey is kept under his name; upon these cards there are indicated every request made for publications, the transmission of every document sent to his address, and every acknowledgment of receipt that he has made; and the groups of cards are arranged alphabetically, so that the account of every correspondent is readily accessible.

The card record of the distribution of this class of documents is supplemented by the correspondence record, since press copies of the letters of transmission of such documents are preserved, as are also the receipts.

Additional records of the custody and transmission of documents are provided in the registry system of the Post-Office Department and in the Smithsonian exchange system. By the former the domestic and by the latter the foreign sendings are conveyed to their destinations. The methods are as follows:

After the documents are prepared for transmission, but before they leave the custody of the librarian, they are separated into

domestic and foreign portions, the former of which are transmitted by registered mail, while the latter are conveyed through the foreign exchange of the Smithsonian Institution. A special record book has been devised for use in the registration of the domestic parcels, by which much labor is saved, both to the Survey and to the Post Office Department, and by which a complete record of the registration of each parcel is kept in duplicate, one copy being preserved in the office of the Survey and the other in that of the registry clerk of the Washington post office.

The parcels of documents going abroad are transmitted in lots to the Secretary of the Smithsonian Institution, with specific instructions for forwarding accompanying each lot. A letter of advice is communicated at the same time to the Secretary, as well as a receipt specifying the number of parcels and the addresses of all. The receipt is duly signed and returned by that officer and a record of the transaction and the receipts themselves are kept in the office of the Survey.

The document system thus described appears to be as simple as is practicable, consistent with the fundamental principles set forth in describing the custodial system of the Survey. It is believed to be so complete that error or peculation could be readily detected at any time after the documents leave the hands of the Public Printer and before they reach the hands of the domestic institution or individual for whom they are designed or until they have passed into the custody of the Smithsonian Institution, the foreign exchange system of which is so widely and favorably known. The system is eminently satisfactory in all respects, save that some delay unavoidably occurs in the transmission of documents to foreign correspondents. Every effort has been made to reduce this delay to a minimum; and it is believed that no further improvement in this direction can be made without material changes in the laws relating to the foreign mail service.

This branch of the Survey is in charge of Mr. C. C. Darwin, the librarian, in whose administrative report certain details of the work of the fiscal year are set forth.

THE LIBRARY SYSTEM.

GENERAL PLAN OF THE LIBRARY.

The establishment of a geologic library as one of the accessory divisions of the Survey has been described in previous reports. As has been pointed out, it is essential that the geologic investigator, if he seeks to maintain a place in the foremost ranks of the science, shall keep himself constantly familiar with the current geologic literature of this and other countries, and since it is the policy of the Survey to employ the ablest geologists it is important that the means of keeping well abreast of geologic science shall be afforded them. Accordingly provision has been made for securing the publications of foreign institutions of learning and science and of scientific specialists as promptly as possible, both by exchange in the manner already set forth and by purchase. No effort is made, however, to build up a general scientific library, but only to make such a collection of scientific books, periodicals, pamphlets, and maps as relate especially to geology or will be of use in the prosecution of the work of the Survey; but certain scientific books and periodicals being of a general character, including contributions to geology in connection with matters relating to other subjects, it is sometimes necessary to obtain publications devoted to general scientific subjects in order to secure the geologic matter. Thus the library of the Survey is fairly supplied with current scientific literature in general and is especially rich in current geologic literature.

The operations of the Geological Survey extend over the entire country; and in order to avoid duplication of labor it is necessary that geologists shall be acquainted with the work of other students in the regions upon which they are engaged. It is therefore important that the library of the Survey shall include all publications upon the geology of the country, whether reports of investigations undertaken by the Federal Government, reports of State surveys, or memoirs embodying the results of the work of unofficial geologists. Great efforts have been made to render the Survey library as complete as possible

with respect to these domestic publications and all the more important ones are now on its shelves.

The general principles of geologic science and of geologic technology are best set forth in the standard treatises and manuals, of which some are classic and invaluable to the student, while many are of high value, and all contain more or less information of use to the investigator in special subjects. It is desirable that the geologist shall have ready access to these standard publications, by the use of which the value of his work is greatly increased, and provision has been made for obtaining such standard treatises on geology as have already been published, as well as those which appear from time to time. This class of publications forms a small but important part of the contents of the library.

Although the most important publications in geology as in other sciences are made either in the form of considerable volumes or in that of articles in standard periodicals, many treatises of considerable importance are either privately printed or published in small editions, generally in pamphlet form; and in order that the library shall be complete it is necessary that these scattered and ephemeral publications shall be collected and preserved. The library is rich in geologic literature of this character.

Thus there are in the library five principal classes of publications, including the foregoing, namely: (1) Official reports by the Federal Government and States, and other publications relating to special localities, (2) standard geologic treatises, (3) scientific periodicals, (4) ephemeral publications, generally in the form of pamphlets, and (5) geologic and geographic maps. As will be seen from the report of the librarian, appended hereto, the number of such documents in the library is large, already reaching 19,501 volumes, 26,100 pamphlets, and 8,000 maps, and a systematic arrangement of the contents of the library is essential to its utility. It is important, too, that a systematic method of accounting for and regulating the custody of the property contained in the library shall be followed, since its contents are of large money value.

Accordingly a comprehensive library system has been devised. It is founded upon the considerations (1) that the contents of the library shall always be readily accessible to the collaborators and employees of the Survey and (2) that the custody of and responsibility for every book, pamphlet, and map shall be constantly fixed by documentary evidence.

ACCESSIONS.

The greater part of the accessions to the library come in the form of exchanges, either by mail or through the Smithsonian Institution; others are obtained by purchase, sometimes in considerable lots, but generally by single volumes or small lots. Great care is required in making out lists for purchase to avoid duplication or purchase of irrelevant matter on the one hand or neglect of desirable publications on the other. All orders for the purchase of books are required to be approved by the Director.

Current accessions in small lots, coming by mail and otherwise, pass through the hands of the chief clerk. A record is kept of the larger lots, either in the account with the Secretary of the Smithsonian Institution, in case they come through the Smithsonian exchange, or by the property clerk, if they are shipped direct.

On receipt the documents are stamped and entered in the accessions catalogue of the library, which contains a short title of the work and notes its condition, binding, &c., and in the case of bound volumes an accession number is added to the stamp and entered in the catalogue and the library label is affixed to the cover. Pamphlets and maps do not have accession numbers and the serials receive accession numbers only when bound. The full title of each book, pamphlet, or map thus received is then transcribed upon a card, which gives the accession number and the date of receipt of the document. These cards constitute, when arranged alphabetically, a complete catalogue of all documents passing into the custody of the library. The bound volumes are then assigned to cases and shelves, an orderly and systematic arrangement being adopted in order that persons only moderately familiar with

the library may easily find publications relating to any area or subject; the pamphlets are assigned to pamphlet cases, in which they are arranged alphabetically; and the maps are placed in cases especially constructed for the purpose.

When books are received unbound and when volumes of periodicals are completed, they are bound in the Government bindery upon requisition of the Secretary of the Interior; and there is a system of recording the making of requisitions, the transmission of volumes to the bindery, and the transmission of the accompanying letters, one to the superintendent of the stationery division of the Interior Department and one to the Government bindery.

On their return from the bindery each volume is labeled and placed in the library, and a separate record of the receipt of the books from the bindery is also preserved.

Maps in single sheets generally require to be mounted on muslin. This is done in the geographic division upon requisition signed by the librarian and countersigned by the chief clerk, and receipts are given by the librarian when the maps are returned. A record of the work is thus kept by means of the requisitions themselves.

The accessions are then a part of the library and ready for circulation. Every volume bears the Survey stamp, printed in indelible ink upon the title page and upon a certain page of the text, and in addition bears the accession number and the Survey label; every pamphlet bears the Survey stamp upon its title page and elsewhere within it; and every map bears the Survey stamp and its catalogue number. There is also a record of every document in the card catalogue, of all except periodicals in the accessions catalogue, of the periodicals in the periodical catalogue, of the maps in the map catalogue, and of most of the documents in the correspondence files of the library.

THE CIRCULATION.

The library is designed for the use of the various collaborators and employees of the Survey, and they are authorized to make requisition for any book, pamphlet, or map contained

therein, except certain standard works of reference which are constantly kept in the library.

The circulation is effected by means of a "call card," which is at the same time a requisition and a receipt for the work desired. The card bears the name of the author or of the series to which the work belongs, the title and date of the work, and the signature of the maker of the requisition, together with his address if not in Washington; and when the volume is issued the accession number is inscribed upon the card, together with remarks concerning its condition, if necessary. These cards are kept in alphabetic order and afford a means of quickly ascertaining what volumes have been withdrawn from the library.

An account is kept with the maker of each requisition upon a card in such manner that the documents in his possession, with their titles and accession numbers and the dates of requisition, can be seen at a glance. This series of cards is also arranged alphabetically, and the accounts of the users of the contents of the library thus afford a check upon the other series. When documents are returned the call cards are either restored to their maker or destroyed and the date of return is entered upon the account card.

By means of this system account is kept of the custody of each document in the library, and in case of loss, destruction, or injury the responsibility therefor can be immediately fixed.

BIBLIOGRAPHIC WORK.

The employees of the Survey engaged in library work acquire a certain familiarity with the contents of the books, periodicals, and pamphlets which they are constantly handling, and assist the investigator materially in his study of the literature of the subject upon which he may be engaged.

The knowledge thus acquired by the library force is utilized in another way. With the growth of scientific literature a need for bibliographies is developed. When properly constructed, a bibliography is to the literature of any special subject what the index is to a single volume; and the preparation of such bibliographies as experience shows to be necessary adds greatly

to the value of libraries. The library of the Geological Survey affords unexampled facilities for the preparation of certain geologic bibliographies the need for which has long been felt by American geologists. Two different bibliographies have accordingly been projected, and work upon them is systematically carried forward in the library. A large part of the work is done during the intervals of leisure occurring in routine work, but in order to keep the subject well in hand the bibliographic work is made the special duty of one of the library force.

The library is in charge of Mr. C. C. Darwin, whose administrative report appears in this volume.

STATIONERY SYSTEM.

The stationery required for the use of the Survey in office and field is not purchased out of the annual appropriations, but is issued from the stationery division of the Interior Department upon requisition of the chief clerk.

The stationery thus drawn from the Interior Department includes not only the articles and materials commonly included under that designation, but (1) certain drawing instruments and materials and (2) the various blanks used in the transaction of the business of the various divisions of the Survey.

Drawing instruments and materials not thus obtained from the Interior Department are purchased out of the annual appropriations, but in the interest of economy outside purchases are reduced to a minimum. Care is taken, however, to avoid false economy in the purchase of instruments and materials and consequent crippling of work. Instruments are less expensive than time; and whenever it appears that the best interests of the public service will be subserved by the use of articles and materials not found in the lists of the Interior Department these are purchased either from the lowest and best bidder under the competitive system or at current market rates, as may be found most expedient in special cases.

It is the policy to provide suitable printed forms and blanks for use in the transaction of business, with a view not only of

reducing clerical labor to a minimum, but of reducing to a minimum the probability of error in making records and keeping accounts. Two hundred and thirty-nine blank forms are printed for the use of the Geological Survey.

Extended use of blank forms is made in what may be designated the autographic card system of keeping records. It has already been shown that the library circulation is effected by means of call cards, made out and signed by persons desiring books. The same method is pursued in other departments of the Survey. Requisitions for photographs, for map mounting, for topographic instruments and supplies, &c. are made upon blank forms printed on card board; receipt is acknowledged on the same card when delivery is made; and the cards themselves, when arranged alphabetically, afford a complete record of the transactions.

The method employed in the stationery system is modeled after that adopted for the Interior Department generally and corresponds in most respects with those pursued in the different Departments of the Government; but in one particular an important modification has been made.

It is an implied term in the contract under which agents of the Government engaged in office work are employed that they shall be supplied with necessary stationery. Now, as fully set forth in preceding paragraphs, one of the fundamental principles in the policy of the Geological Survey is that in the custody of property of all kinds there shall not only be documentary responsibility, but that the actual responsibility shall coincide therewith. This principle is applied in the stationery system. The requisitions for stationery are made out in the name of the individual who requires the article or instrument; they are then countersigned by the chief of party or division, approved by the chief clerk, and filed alphabetically under the names of the persons to whom the property is issued. So there is a personal responsibility for every article issued from the stationery department, and that responsibility is not distributed over a division, a party, or even a single room. The chief of division shares the responsibility with the subordinate

only in that he indorses his request and the chief clerk shares the responsibility only in that he indorses the certificate of the superintending officer; it is the individual that actually uses the property who is held responsible therefor upon the records of the institution. It is believed that this method of fixing responsibility tends decidedly to check extravagance and waste.

There is a stationery room in the office of the Survey, which is in charge of a clerk, assisted by one or more messengers, as may be required from time to time.

THE CORRESPONDENCE SYSTEM.

The correspondence of the office is carried on in three divisions, namely: in the editorial and miscellaneous division, in the office of the chief disbursing clerk, and in the library.

In the first two divisions the system is that adopted by the Interior Department, modified by substituting a card index for the index entered in a volume kept for the purpose. The card index is found to be far superior in convenience and in economy of time and labor. By it the arrangement of entries is alphabetic, not simply under initial letters, but throughout, and the finding of entries is thereby greatly facilitated. The card index is also susceptible of indefinite extension; it permits the modification or exclusion of entries without defacement; and the cards afford space for fuller briefs and memoranda than can well be introduced in a volume. Much of the time and clerical labor required in finding letters by means of the index in a volume is saved by the employment of the card index; there is a corresponding saving in the time of the individuals for whose needs the index is consulted; the first cost of the card index is also much less than that of the bound volume usually employed for that purpose; and, finally, the card index is type-written and bound at the end of the year, affording a permanent index much more convenient and serviceable than that kept in a volume in the usual way.

In the library the correspondence is of a special character, relating exclusively to documents and library matters, and in the interests of economy authority has been obtained from the

Secretary of the Interior so far to modify the correspondence system of the Department as to merge it into the library and document systems already described. The letters sent are recorded upon cards which are alphabetically arranged in the same manner as the address cards of foreign and domestic correspondents of the Survey, while the letters received are themselves arranged alphabetically under the names of correspondents in cases provided for the purpose. The correspondence of each year is assembled at the end of the year under an alphabetic arrangement by authors and a chronologic arrangement within the year under each author.

THE GENERAL ADMINISTRATIVE SYSTEM.

The administrative authority vested in the Director and his responsibility are either expressed or implied in the organic law of the Survey or clearly indicated by the general laws, customs, and regulations relating to the administrative affairs of the Federal Government. The manner in which the administrative function is exercised and in which responsibility is met has been sufficiently set forth in preceding paragraphs.

The directions in which and the extent to which administrative authority is delegated and responsibility transferred in the scientific and business branches of the Survey have been shown in detail in the description of the several business systems of the Survey. As set forth therein, large authority is delegated in the scientific branch of the Survey and responsibility is secured through the method of allotments under which the officers in charge assume responsibility, not only to the Director but also to the scientific public, for the work performed in their divisions. In the non-scientific branches, on the other hand, authority is not delegated, except so far as is essential to the successful performance of the work of the Survey, and responsibility is secured through a system of regulations by which disbursing officers are bonded, by which records and accounts are systematically kept, by which individual responsibility for all fiscal transactions is shown by documentary evidence, and by which the responsibility for all property in the control of the Survey is similarly fixed.

Certain important administrative duties grow out of these methods and regulations, foremost among which is that of securing observance of the methods and regulations adopted throughout the complex organization. Practical considerations have necessitated the division of this and related duties into (1) those which are necessarily performed by the Director in person and (2) those which while performed under the immediate supervision of the Director may yet be delegated to a trustworthy officer.

(1) Excellence of scientific work is secured, first, by publishing the results thereof under the names of the authors, who thereby assume responsibility not only to the Survey but to the scientific public for their work, and, secondly, by careful examination and discussion, and when necessary thorough revision, of the reports prepared for publication. The Director assumes a limited responsibility to the scientific world for the excellence of the work performed in the Survey, a responsibility equaled in weight and in importance to the country only by his financial responsibility, and it is therefore incumbent upon him to determine personally the quality of all material published by the Survey. This duty cannot be delegated except in a limited degree.

In order that the adoption of bad or extravagant methods and unwise policies may be prevented, it is necessary that the Director shall be constantly informed of the progress of the work of the Survey in every part of the country. Accordingly, chiefs of division are required to submit detailed monthly reports of operations, with such statement of plans and purposes as may be required to indicate the character of prospective operations. For like reasons chiefs of division are required to present plans and estimates for the ensuing year toward the end of each fiscal year, and use is made of these statements in preparing the general plan of operations for the Survey for each year. It is for the same reasons, too, that the administrative reports of chiefs of division are prepared annually. By all these means the Director is enabled to determine at any time the precise condition of the work in all parts of the country, to plan for extension or contraction in different

areas, to modify methods, and to adjust means to ends in such manner as to produce the best results to the Survey and to the country at large.

The reports of chiefs of division, monthly and annual, are used in another way: The Director digests and summarizes the monthly reports of the various divisions and promptly submits the summaries to the Secretary of the Interior; and the annual administrative reports are incorporated in the annual report of operations made to the Secretary of the Interior and by him submitted to Congress.

The financial responsibility of the Director is large and has not only led to the development of the fiscal system of the Survey, but renders it necessary that he shall personally examine the records of all fiscal transactions and satisfy himself as to the necessity and integrity of each in the manner described in an earlier part of this report.

The library is an essential part of the machinery of the Survey, and upon its completeness the efficiency of the scientific work is in a measure dependent. It is desirable, however, that the expenditure of funds for the maintenance of the library shall be reduced to a minimum, and it is therefore important that the system of exchanges be rendered as complete as possible. Accordingly the Director gives personal attention to all matters concerning the growth of the library, including orders for purchases and all additions to the exchange list.

The expense of illustrating and publishing the reports of the Survey is large, and much thought has been given to this subject with the object of reducing both the cost of illustrations and the cost of publication so far as may be consistent with the satisfactory presentation of the results of the work. Plans for securing these ends have been developed, as already indicated; but special questions arise in connection with nearly every publication, and it is important that they shall be carefully decided. All such questions are submitted by the chief of the illustration division to the Director, who thus gives personal attention to all essential matters pertaining to illustrations, and all business with the Public Printer is transacted through him.

One of the results of the division of labor extending throughout the Survey is that collaborators frequently find it necessary to call upon other specialists for assistance in their investigations. For example, the geologist may need to have certain fossils identified, certain rocks, minerals, or soils analyzed, certain ores assayed, or certain rocks examined microscopically, and sometimes the same geologist may at the same time require assistance from several divisions of the Survey, and might, if there were no restriction, absorb the energies of a considerable portion of the Survey force to the detriment of its general progress. It is necessary to prevent undue concentration, to distribute properly the energies of the Survey in the most desirable channels, and to keep the researches in different directions and the work of the different divisions as nearly in line as practicable. To secure this end it is provided that all requisitions for the collaboration of specialists or the assistance of other divisions shall be authorized by the Director.

Thus the Director supervises not only in general but also in detail all of the scientific operations of the Survey and all of the results of such operations, and in addition all matters pertaining to the fiscal system of the Survey, to publication and illustration, and to the conduct and growth of the library.

(2) Under the organization of the Geological Survey as affected by the provisions of sections 177–179 of the Revised Statutes, the chief clerk is the second administrative officer of the Survey and the official representative of the Director in his absence, and various general administrative duties of minor importance are delegated to that officer; but they are performed under the general direction and supervision of the Director.

In the principal office of the Survey, at Washington, there are employed upon the work of the Survey from seventy persons in summer to two hundred and twenty-five persons in winter in a building of seventy-eight rooms on five floors, and it is necessary that the best systems of work shall be adopted, that the time of all employees shall be advantageously occupied, and that regulations concerning hours of labor, specific duties, &c., in accordance with Government usage, shall be

made and enforced. Attention to such matters is one of the functions of the chief clerk.

Large quantities of stationery and considerable office furniture &c. are necessarily used in carrying on the work of the Survey. As already stated, it is an implied term in the contract of an employee of the Government in Washington that he shall be supplied with necessary furniture, stationery, &c.; but, in order that waste may be prevented, it is necessary that requisitions for such property shall be carefully scrutinized by an administrative officer and indorsed only after it has been found that the property is actually required. It is accordingly provided that all requisitions for office furniture, stationery, drawing instruments and materials, laboratory apparatus and materials, &c. shall pass through the hands of the chief clerk and shall receive his indorsement before being honored.

In addition to the instruments &c. required for the use of the geographic division a large amount of miscellaneous property is necessarily purchased for the use of the different geologic and topographic parties in all parts of the country. A portion of this property can be most advantageously acquired in the field, but a considerable portion can be more economically purchased in Washington and shipped to the points at which the parties outfit; and there is an incidental advantage in making purchases in Washington in that the keeping of property records and accounts with allotments is thereby facilitated. In the outfitting of each party, therefore, it is desirable to consider carefully the relative economy of purchase in the field and of purchase in Washington, which involves the payment of cost of transportation. This difficult duty is delegated to the chief clerk, and all requisitions for miscellaneous property required in the outfitting of parties pass through his hands and the best method of making purchases is decided by him in each case.

As already shown, extensive use is made of photographs, sketches, &c., both for working purposes and for purposes of illustration, and large numbers of maps are mounted, both for the use of the library and for the use of geologists and topographers employed in the field. In these processes time and materials

are consumed, and it is desirable that such consumption shall be reduced to a minimum by reducing the use of such photographs and maps so far as may be consistent with the satisfactory execution of the work of the Survey. Accordingly, it is provided that such work shall be done on requisition, and these requisitions pass through the hands of the chief clerk, who satisfies himself as to the necessity for the work before affixing his signature.

The correspondence of the Survey is large and, as already set forth, is carried on in three divisions, and it is consequently necessary that all correspondence shall be properly assigned. For this reason it all passes through the hands of the chief clerk, who has general oversight of the correspondence wherever carried on.

The same officer exercises supervision over the property returns and all other matters pertaining to the custodial system, and over the editorial, illustration, document, and library systems, except as otherwise indicated above, and in general co-ordinates and distributes the energies of the business branch of the Survey, except in regard to fiscal matters.

The varied as well as arduous and important duties attaching to the office of chief clerk are performed in an eminently satisfactory manner by Mr. James C. Pilling.

THE SURVEY REGULATIONS.

To facilitate the transaction of business by employees of the Survey in accordance with the principles and methods set forth in the preceding paragraphs, the regulations of the Survey were codified and printed in 1882 in a bound volume of fifty-two pages. This volume contains (1) the organic law of the Survey, with instructions relating to its provisions; (2) instructions relating to money and property, comprising schedules of authorized expenditures for services, transportation, field subsistence and supplies, instruments, laboratory and photographic material, stationery, drawing material, office furniture, &c., with various necessary instructions to disbursing agents and custodians of property; (3) instructions relating to bonded

railroads and the transportation of both individuals and property; (4) instructions relating to the collection of specimens &c.; (5) instructions relating to publications; and (6) miscellaneous instructions. Whenever necessary, these instructions are illustrated and the methods are exemplified by the reproduction of the blank forms employed, properly filled out. Copies of this volume are placed in the hands of chiefs of division and heads of parties.

SUMMARY.

It will be seen from the foregoing statement that three principal requirements are constantly recognized in the organization and policy of the Geological Survey.

The first requirement is that the work of the Survey shall be performed in the most efficient manner. It is sought to meet this requirement by securing the collaboration of the most eminent specialists in geology and cognate branches of science and the most thoroughly skilled topographers and assistants of various grades to be found in the country, by the application of the principle of the division of labor to the fullest possible extent, by reducing to a minimum the routine and administrative work necessarily performed by the scientific collaborators, and by the adoption of a convenient library system.

The second requirement is that the results of the work of the Survey shall be rendered accessible and valuable to the general public. This end is attained in part by intelligent legislation relating to publication and by laws governing the disposition of the publications of the Survey, and this legislation is supplemented by the exercise of care in the preparation and detailed revision of reports, by the extended use of graphic illustrations and such diminished expense in producing them as will permit of their wide application, and by the adoption of a carefully devised document system.

The third requirement is that the most rigid economy consistent with the primary functions of the Survey shall be exercised. It is believed that this requirement is fairly met by

the custodial, fiscal, stationery, and related business systems, by the application of new and economic methods in the illustration system, by the constant division of labor, by the method of allotments to responsible collaborators for stated purposes, and by the application in every division of the Survey of the principles (1) of fixing responsibility by documentary evidence and (2) of rendering the documentary responsibility coincident with the actual responsibility.

For reasons that have already been mentioned, the personal organization is less complete than the differentiation of function in the branch of the Survey devoted to the transaction of business; different lines of work are sometimes performed in the same division and the same class of work is sometimes divided between two or more divisions; and in so far as has been found to be expedient the business operations of the Survey are conducted by the scientific collaborators. Moreover, certain divisions of the Survey—e. g., the library and division of illustrations—are organized for the performance of duties which are semi-scientific in character, and these divisions accordingly may be referred with almost equal propriety to the scientific or to the business branch of the organization. This explanation is necessary to a complete understanding of the accompanying schedule showing the business organization of the Survey.

SCHEDULE OF BUSINESS ORGANIZATION.

Chief clerk	James C. Pilling.
Section of stationery	L. S. Meador.
Division of disbursements and accounts	Jno. D. McChesney.
Custodian of property	J. E. Allen.
Division of illustrations	W. H. Holmes.
Photographic laboratory	J. K. Hillers.
Editorial and miscellaneous division	Thomas Hampson.
Division of library and documents	C. C. Darwin.

WORK OF THE FISCAL YEAR.

THE PROGRESS IN TOPOGRAPHY.

During the fiscal year topographic surveys have been carried forward in accordance with the general plan of the Survey, which has been described in previous reports, and satisfactory progress has been made in the various regions already entered upon. The aggregate area surveyed by the different sections was 55,684 square miles. The distribution of the work is shown graphically in the accompanying Plate I (in the pocket at the end of the volume). The areas surveyed in the several States and Territories into which the operations of the geographic division have extended, the scales upon which the work has been executed in each, and the contour intervals are shown in the following table:

Areas surveyed during the year ending June 30, 1887.

State.	Scale of publication.	Contour interval in feet.	Approximate areas in square miles.
Alabama	1: 125, 000	100	900
Arizona	1: 250, 000	200	7, 620
California	1: 125, 000	100	3, 025
Georgia	1: 125, 000	100	3, 400
Kansas	1: 125, 000	50	5, 940
Kentucky	1: 125, 000	100	1, 100
Maryland	1: 62, 500	20	279
Massachusetts	1: 62, 500	20	3, 200
Missouri	1: 125, 000	50	4, 500
Montana	1: 250, 000	200	3, 300
New Jersey	1: 62, 500	10 and 20	1, 340
North Carolina	1: 125, 000	100	2, 500
Oregon	1: 250, 000	200	3, 000
South Carolina	1: 125, 000	100	1, 900
Tennessee	1: 125, 000	100	1, 200
Texas	1: 125, 000	50	4, 430
Virginia	1: 125, 000	100	5, 700
West Virginia	1: 125, 000	100	2, 350
			55, 684

As in preceding years, the areas surveyed during the field season have been mapped during the office season by the topographers who executed the surveys.

As the maps are completed they are placed in the hands of the engraver and reproduced upon copper plates in accordance with the plan set forth in preceding reports, and a small edition of proof copies has been printed for the use of the office. The atlas sheets which have been engraved during the year are tabulated in the accompanying administrative report of the officer in charge of the work of the division of geography, Mr. Henry Gannett. The total area covered by the engraved atlas sheets of the Survey up to date, arranged by States, with the number of sheets and parts of sheets to each State and the scales and contour intervals, is shown in the accompanying table:

Areas covered by atlas sheets engraved up to June 30, 1887.

States &c.	Number of sheets.		Contour intervals in feet.	Approximate areas in square miles.
	Wholly in State.	Partly in State.		
Alabama	1	3	100	2,200
Arizona	12	2	200	50,000
California	6	1	200	23,000
Georgia	1	4	100	3,800
Kansas	4	4	50	7,000
Kentucky	1	5	100	3,500
Maryland	2	2	100	600
Massachusetts	3	....	20 and 40	700
Missouri	12	2	50	13,000
Montana	3	....	200	11,000
Nevada	3	3	200	20,000
New Mexico	2	....	200	8,000
North Carolina	1	8	100	3,800
South Carolina	....	1	100	200
Tennessee	5	11	100	10,500
Texas	12	....	50	12,000
Utah	17	1	250	65,000
Virginia	....	11	100	5,500
West Virginia	3	7	100	6,600
Wyoming	....	2	100	600
Yellowstone Park	2	2	100	3,000
				250,000

During the last year topographic work was pushed forward vigorously in Massachusetts, at the joint expense of the State and Federal Governments, in accordance with the terms of a contract described in an earlier report, and the survey of the State is now nearly completed; the sheets already finished have been examined and approved by the commission of supervision on the part of the State and three of them have been engraved. The condition of the work is shown by Plate II. Partly for the purpose of illustrating and testing the manner in which the atlas sheets of the Survey can be utilized in the construction of general maps of reduced scale—the Übersichtskarten of the Germans—and partly to exhibit the wide applicability of the general plan of topographic map construction adopted by the Survey and already described, the preparation of a general map of Massachusetts, based on the atlas sheets, has been commenced. It is being drawn upon a scale of 1:300,000, and, as in the atlas sheets, the hydrography is in blue, the hypsography in brown, and the culture in black.

The topographic survey of New Jersey was practically completed during the year, as will be seen from Plate III, appended to the report of the geographic division.

The survey of the District of Columbia and the contiguous portions of Maryland and Virginia falling upon the same atlas sheets, comprising an area of 450 square miles, bounded by the parallels 38° 45′ and 39° and the meridians 76° 45′ and 77° 15′, respectively, has been completed during the year. The drawing is also finished and after a critical review of the work the sheets will be engraved. It is a remarkable fact that while certain special maps covering portions of the District of Columbia and contiguous country have been constructed by the Engineer Corps of the Army, while the admirable surveys of the Coast and Geodetic Survey have been extended along the Potomac River in the vicinity of Washington, while several sheets of a magnificent map of the District (in contours with vertical intervals of 5 feet) have been issued from the office of the District government, and while certain other special maps as well as a large number of general maps representing the area have been constructed, there has never yet been pub-

lished a complete and accurate topographic map of the National Capital and its environs; accordingly the map now completed will fill a widely felt want.

In the southern Appalachian region work has been actively prosecuted with a large force. The survey of the mountain region proper is approaching completion and a considerable part of the force was employed during the year upon its flanks and its southern extremity. The extraordinary development of the mineral resources of this region which is now taking place, together with attendant extension of railroads, gives these maps a high value, as is shown by the great and ever increasing demand for them.

The work in Missouri, Kansas, and Texas has made satisfactory progress, that in Kansas having been extended westward to the ninety-seventh meridian across the whole breadth of the State.

The surveys in Arizona have been extended to cover the southern border of the great Colorado plateau.

The work in the gold belt, upon the western slope of the Sierra Nevada in California, has made good progress, and that in the northern part of the State has been extended northward up the Cascade Range into Oregon.

The survey of the Yellowstone National Park having been completed during the previous year, the work has been extended north and west into Montana during this year.

The work of the division of geography consists in the production of maps of a degree of accuracy and detail suitable for publication upon certain specified scales at a minimum of expense. The standard of work is set by the scale and the study of the topographer is to devise such methods as will meet the requirements of the scale at the least cost. This view of the work seems to be sound and scientific and the only one which duly proportions means to ends. It necessarily follows that, under different conditions of surface, of culture, and of scale, variations in method are found necessary. The bold relief of the Rocky Mountains cannot be economically surveyed by the methods which are employed in the level, forest-clad region of the Atlantic plain; the dense settlement of New

England imposes methods which are not economically applicable in Montana; while it is easy to understand that in many cases methods which are best for the production of maps upon the four-mile scale measurably fail when applied to the one-mile scale. It follows that improvements in methods and instruments, in the direction of better adapting the work to topographic conditions, are constantly being devised, while the inception of the work in new regions, which present features not before encountered, renders necessary more or less modification of methods of work to meet the new conditions. Sufficient work has now been done to furnish fairly trustworthy averages of cost, while the accuracy, the amount, and the distribution of the geometric control of the work can be characterized quantitatively, as illustrated in the report of the chief of the division of geography.

PROGRESS IN GEOLOGY.

PLAN FOR THE GEOLOGIC MAP.

At the inception of the Survey the prospective operations upon different lines were definitely projected in accordance with the terms of the law providing for the construction of a geologic map of the United States. These plans were, however, affected by various conditions: Thus by specific enactment the Geological Survey inherited the work of certain surveys previously instituted by the Federal Government and it was necessary to provide for carrying on and completing the work already commenced. Again, for the purpose of utilizing as rapidly as possible the results of geologic investigation in different portions of the country, arrangements were effected for incorporating the results of certain official and unofficial surveys in progress in several States, and the general plan of the Survey was so far modified as to render the work of such surveys immediately useful. Moreover, the mineral resources of certain regions were attracting attention and it was deemed wise to commence operations in those regions in which the resulting benefits would be greatest and most quickly realized. Finally some of the geologists whose collaboration was secured by the

Geological Survey at the commencement of its work were especially familiar with particular areas and in a position to carry on investigation in such areas more advantageously than in any other, and, so far as was practicable, they were assigned thereto. So, for various reasons, geologic work was in many cases commenced in regions not topographically surveyed, and there has accordingly been delay in completing and publishing the portions of the prospective map of the United States covering the territory within which this preliminary work was undertaken. In most cases, however, the topographic surveys preceded the geologic work, in accordance with the general plan of the Survey. In certain portions of the country the geologic studies are approaching completion and the geologists are in a position to project the results of their work upon the atlas sheets, and, in fact, many sheets are already colored geologically in manuscript, but there is reason for delaying their publication.

In order that the geologic map of the United States shall be of the greatest possible value to all classes of users it is necessary that it shall be prepared upon a uniform plan, that a uniform system of classification shall be employed for the different portions of the country, and that, so far as possible, the same colors shall be used for identical formations and geologic groups throughout the country. But the task of devising a cartographic system which shall meet these requirements is one of great difficulty. Much thought has been given to the subject during recent years by the geologists of this and other countries. There is an International Geological Congress which has for its principal object the development of a uniform method of geologic mapping and the unification of geologic classification and nomenclature; this body, including the most eminent geologists of the world, considered these subjects at great length at Paris in 1878, at Bologna in 1881, and at Berlin in 1885. There is an official committee of American geologists who represent the interests of this country in the International Congress and who have given prolonged consideration to the subjects; but no final results have been reached by the committee or the congress. The Director of the Survey is a mem-

ber of the American official committee and has participated in its deliberations as well as in those of the International Congress. He has in addition given much attention to the development of a cartographic system suitable for the purposes of the Survey. Considerable space was devoted to this subject in the Second Annual Report and numerous experiments have since been made for the purpose of testing different color schemes.

No fully satisfactory cartographic system has thus far been developed, although a system has been devised which reasonably meets the requirements of this country and is objectionable chiefly in that it is in a measure inconsistent with foreign usage; the wisdom of finally adopting it is, therefore, in a degree doubtful. There will, however, be another session of the International Congress at London during the ensuing year and it is hoped that a cartographic system may there be agreed upon which will meet the requirements of this Survey and at the same time be acceptable to the geologists of other countries and suitable for all purposes of geologic science. Meantime it is regarded as injudicious to publish maps colored in accordance with a plan which may have to be modified or abandoned.

WORK OF THE GEOLOGIC DIVISIONS.

During the year investigations of the Archean rocks have been rapidly pushed forward in New England by Professor Pumpelly and in the Lake Superior region by Professor Irving. Satisfactory progress has been made in both regions, though in the former this progress has lain rather in the direction of the development than in that of the solution of problems. The region is one of great complexity in geologic structure and has puzzled and has been in a measure a field of dispute among the geologists of three generations; and it is necessary to proceed with caution, in order that every result reached may be final and beyond the reach of criticism. Professor Irving's work has been quite successful as measured by results. He has elucidated the structure of the iron bearing and copper bearing rocks along the southern and western shores of Lake Superior, making in the progress of his work important con-

tributions to geologic taxonomy and securing data of great economic value to this region of rapid industrial development.

Professor Shaler's investigations of the tide marshes and inundated lands of the Atlantic coast have kept before him the question as to the oscillations of the land and the alternating emergence and submergence of different parts of the coast. These changes of level have been studied at different points, and the results of a detailed investigation of the old shore lines and related phenomena upon the island of Mount Desert form one of the papers accompanying this report. The practical work upon tide marshes has meantime progressed satisfactorily.

Mr. Gilbert's work upon the structure of the Appalachian mountains and upon the movements yet in progress in this region have been eminently satisfactory. Several sections, extending from the plateau of simple structure on the west through the mountains to the Piedmont plateau on the east, have been completed. They clearly indicate the structure of the mountain system and the distribution of the coal seams, iron ore beds, limestone layers, cement deposits, &c. found in the mountains and along their western flanks. A special treatise on the bituminous coals and the natural gas and oil of West Virginia has also been prepared. Among the results of the year's work in this division there should be mentioned also the careful resurvey of Niagara Falls, executed by Mr. Woodward, for the purpose of comparing the present condition of the falls with that during earlier years and thus determining the rate of recession. This great cataract has long been regarded the most trustworthy chronometer known for geologic time and it is believed that it affords one of the most satisfactory means for the reduction of geologic time units to historical time units.

The investigations in glacial geology under Professor Chamberlin have been carried over nearly the entire glaciated area of the United States. Many of the fields remaining unexplored a year ago have been carefully examined during the present year, and the field work is thus nearly completed. Meantime, maps and reports exhibiting the classification and distribution of the glacial and aqueo-glacial soils of the north-

ern part of the United States have been in preparation. The relations of geology to agriculture are through chemistry, and during the year Professor Chamberlin has given attention to soil classification upon the basis of geologic structure and chemic and physical constitution combined, with the object of facilitating the application of strictly scientific methods in agriculture.

The studies already commenced in different parts of the Rocky Mountain region have been satisfactorily pursued. The combined investigations of the general geologic structure and of the coal, oil, gas, &c. of Montana have been somewhat crippled by the long illness and finally by the consequent resignation of the veteran geologist Dr. Ferdinand V. Hayden, to whom so large a debt of gratitude is due from the people of the country for his activity in originating and prosecuting some of the most important surveys ever undertaken in the United States. The work, however, was not abandoned or even discontinued and during the latter part of the year has been carried forward in accordance with the old plans by Dr. Peale.

The systematic observations already commenced by Mr. Hague in nature's great laboratory in the Yellowstone National Park have been carried on actively and have resulted in much additional information concerning the origin and relations of certain mineral deposits.

The investigations of the structural and mining geology of Colorado by Mr. Emmons have also been pushed forward as rapidly as possible. Among the results of the year's work in this division should be mentioned the completion of an extended study of the Denver coal field and the commencement of the preparation of a special report thereon.

By reason of the completion of one field of investigation the operations of the California division have been divided. A part of the force has been employed during the year in a study of the auriferous zone along the western flanks of the Sierras, known as the gold belt, and, although final results have not yet been reached, much information of great practical utility has been collected. Mr. Becker has completed his report

upon the quicksilver mines of the United States. In order that his monograph upon this rare and unequally distributed mineral deposit might be exhaustive, it was deemed necessary that he should personally examine the quicksilver mines of Almaden in Spain, and a visit to Spain for that purpose was authorized by the Secretary of the Interior. Mr. Becker's monograph will go to press at an early date.

The principal field operations of the volcanic division, under Captain Dutton, were confined to the great lava fields and the various volcanic deposits of Northern California and Southwestern Oregon. Exceedingly valuable results, in the form of data relating to the origin and constitution of lavas and to the ascertainment of the part which volcanism has borne in the history of Western America, were secured. Captain Dutton was greatly aided in his researches by Mr. Diller, who contributes to this volume a paper embodying a portion of the results of the work of this and previous seasons. Among the incidents of the year's work may be mentioned the exploration, sounding, and mapping of the unique body of water called Crater Lake, which, as its name implies, occupies an old volcanic vent and which was found to be the deepest body of fresh water known on this continent. During the latter part of the year the energies of the division were devoted largely to the investigation of the Charleston earthquake, to which reference is made elsewhere.

By reason of the rapid industrial development of Northern Mississippi and Louisiana and the consequent opening of numerous excavations exposing the rocky strata, much attention has been given to mineral resources, and the time of Mr. Johnson, the geologist employed in this region, has been too largely occupied in field examinations to permit of the preparation of final reports setting forth fully the results of his work. Valuable information has, however, accumulated rapidly in his hands and has been disseminated among the people, both orally and through the local press, and preliminary reports upon the Tertiary deposits and the intercalated iron ore and marl beds of the region are in press.

The field work performed during the year in the Potomac division has been confined chiefly to the Quaternary deposits of the coastal plain between North Carolina and New York and has resulted in considerable additions to our knowledge of the Quaternary history of the Atlantic slope. As during previous years, however, the larger part of Mr. McGee's time has been absorbed in administrative work. One of his duties was the examination of the central part of the area affected by the great Charleston earthquake immediately after its occurrence.

The subjects of investigation and the methods pursued in the various geologic divisions are set forth at length in the accompanying administrative reports. The results of the work are not incorporated in these reports, except in so far as may be necessary to the explanation of subjects and methods of study, but are incorporated in certain of the papers accompanying this volume and in other current publications of the Survey.

PROGRESS IN PALEONTOLOGY.

METHODS PURSUED.

There are two lines of paleontologic investigation the objects and applications of which are in a measure different. The first of these is the biotic and the second may be designated the technic.

The first line of investigation has for its object the determination of the biotic relations of faunas and floras, the elucidation of the life history of each animal and plant whose remains are preserved in the rocks as fossils, and ultimately the unfolding of the entire life history of the globe; and it has for one of its applications the determination of the value of fossils as criteria for geologic discrimination and classification.

The second line of investigation has for its immediate object the collection and arrangement of fossils from the rocks of the country and the investigation of the relation between these fossils and geologic structure in such manner that the fossils may be classified by geologic structure or even geographic distribution and that a composite taxonomy involving both

rocks and fossils may be developed; and its application is the identification, correlation, and classification of the formations of the country required in the construction of geologic maps.

In the Geological Survey these two lines of investigation are combined so far as practicable, as the technic study of fossils is most thoroughly carried on in the light afforded by a knowledge of their biotic relations.

RESULTS ATTAINED.

During the year Professor Marsh has continued his studies of the gigantic vertebrates of the Western Territories. He has collected a large amount of new material, has prepared several skeletons and parts of skeletons from the rough material collected during preceding years, and has nearly completed for the press a monograph on the Stegosauria, in which it is believed the high standard already established in this class of work will be maintained. The results of the work of this division have already attracted profound attention among scientific men, not only in this country but throughout the world.

A large part of Mr. Walcott's work has been performed in the belt of complicated geologic structure in the eastern part of the upper Hudson Valley, a region in which displacements by flexure of the Appalachian type and by faulting of the Great Basin type are combined, in which the surface is mainly drift covered, leaving few exposures of rock, and in which the topographic details have been fashioned by Quaternary ice rather than determined by the underlying rock. It is the western part of that zone of obscure relations which has formed the subject of the well known Taconic controversy; but, despite the large amount of labor that has been expended upon the region and the literature that has grown out of it, this of all the geographically known portions of the country remains the terra incognita of American geology. Professor Pumpelly approaches the Taconic range from the east and Mr. Walcott from the west and both have attained valuable results. The work of the latter has been stratigraphic rather than paleontologic and the fossils have been used solely as indications of

the geologic structure. Other lines of Mr. Walcott's work are described in his administrative report.

One of the most important events of the year in systematic geology was the discovery by Dr. White and Mr. Hill of a great series of Cretaceous strata in the State of Texas underlying the rocks hitherto regarded as the base of the American Cretaceous and corresponding in many respects with the Lower Cretaceous deposits of Europe. Preliminary notices of the discovery have already been made in the scientific journals by both of these gentlemen and have attracted considerable attention and widespread interest both in this country and abroad. The relations of this series to the deposits yielding salt, sulphur, iron, &c. in Texas, Louisiana, and Mississippi have not yet been fully made out, but are under investigation. The bearing of the discovery upon the question of artesian water supply in the arid plains of Central Texas is most intimate and information on this subject of immediate practical value has been conveyed to the people of the State through the public press. Other lines of work performed in this division are described elsewhere in this volume.

In the earlier days of geology, certain tacit assumptions relating to the geographic distribution of animals, particularly during later geologic time, were necessarily made; but, in order that fossils shall have their greatest value as criteria for the identification and classification of the rocks of the Tertiary, it is necessary that these assumptions shall be questioned and that the actual distribution shall be ascertained by careful examination in favorable areas. During the year Dr. Dall's studies have thrown much light on the distribution of genera and species in certain of the Tertiary deposits of the coastal plain on both the Atlantic and Gulf slopes. In the prosecution of his work large collections have been made and the series of representative and type fossils required for the geologic study of this portion of the country has been greatly enriched.

It has already been made known that, in order to prepare the way for comprehensive study of the fossil plants of this country, Professor Ward has undertaken the preparation of a compendium of paleobotany. This monograph is now ap-

proaching completion and some of the information collected in the course of its preparation is incorporated in a treatise appended to this report. Meantime Professor Fontaine, of the University of Virginia, who is associated with Professor Ward during a portion of each year, has continued his work on the plant remains of the Potomac formation. The flora represented by these fossils is unique and exceedingly luxuriant. The formation appears to occupy a position intermediate between the Cretaceous and Jurassic of the European series, but its exact equivalent is not known in any other part of the globe. The flora is of especial interest in that it represents the period of transition from primitive polycotyledonous forms of early geologic time to the dicotyledonous forms which have since prevailed throughout the globe. Drawings and descriptions of more than three hundred and fifty species, of which over three hundred are new to science, have been prepared during the year, and the text of a monograph on the subject is completed and will go to press within a few months. Meantime another novel line of investigation has been taken up by Mr. Knowlton, viz, the study of petrified and lignitized woods, with the object of discovering methods of utilizing such material in geology as criteria in classification. The preliminary results of this work are set forth in a paper soon to appear as a bulletin of the Survey.

Mr. Scudder's studies of the fossil insects of the country have progressed satisfactorily. A memoir comprising descriptions of American genera and species appears in this volume.

WORK OF THE ACCESSORY DIVISIONS.

CHEMISTRY AND PHYSICS.

In conaucting the operations of the Survey it is constantly borne in mind that while the common and simple petrographic classification of rocks belonging to the stratified series suffices for all practical purposes, as well as for most of the purposes of geologic study, every system of classification and nomenclature of the crystalline rocks of the earth thus far proposed is more or less objectionable, and the possibility that the ultimate

classification of these rocks may have a purely chemic basis is recognized. Thus, in the prosecution of the work of this division, as in that of the paleontologic divisions, a double object is ever kept in view: not only are such analyses and assays made from time to time as are required for the solution of the practical problems which arise daily in the geologic work, but efforts are constantly made to ascertain the ultimate relations of the chemic elements and compounds and the rock forming minerals, in order to establish as quickly as possible new and improved criteria and methods of mineral classification. In thus pursuing the chemic studies of the Survey upon a broad plan, field work in representative mineral localities occasionally becomes necessary. Several such localities have been visited by Professor Clarke during the year, each yielding valuable information or material.

An important subject of study in this division during the year embraced the salt and soda deposits and the saline lakes of the Great Basin in Utah, Nevada, and California. Thus far the vast accumulations of brine and saline precipitates in this region have not been fully utilized, partly by reason of inadequate means of transportation and partly by reason of ignorance as to their extent and value. Mr. Chatard's work has done much to direct attention to these important resources and to enable prospective investigators to determine the conditions under which investments may be made.

Perhaps the most complete study of the mineral waters of any locality with special reference to their agency in mineral formation ever placed on record is that completed during the year by Messrs. Gooch and Whitfield, of this division. This study comprises a part of the results of the investigations now under way in the Yellowstone National Park. The application of its results will be made in the final reports on that interesting locality of modern mineral deposition; but, meantime, the results themselves will be published in the form of a bulletin.

Other lines of investigation have also been pursued in this division and are described at some length in an accompanying administrative report.

MINING STATISTICS.

As during previous years, much labor has been devoted to the collection of statistics of mines, mining, and mineral production, partly for use as a guide in the plans and operations of the Survey and partly because such information is of great value to the country and so intimately connected with geologic work as to form a legitimate part thereof. Mr. Day, who has charge of this division, has during the year improved and perfected his method of collecting statistics and has enlarged his corps of correspondents; and the value of the information collected is thereby increased.

The accompanying tables exhibit the quantities and values of the various metallic and non-metallic mineral products of the United States during the calendar year 1886:

Metallic products of the United States in 1886.

	Quantity.	Value.
Pig iron, spot value .... long tons..	5,683,329	$95,195,760
Silver, coining value .... troy ounces..	39,445,312	51,000,000
Gold, coining value .... do.....	1,881,250	35,000,000
Copper, value at New York City .... pounds..	a161,235,381	16,527,651
Lead, value at New York City .... short tons..	135,629	12,667,749
Zinc, value at New York City .... do.....	42,641	3,752,408
Quicksilver, value at San Francisco .... flasks..	29,981	1,060,000
Nickel, value at Philadelphia .... pounds..	214,992	127,157
Aluminum, value at Philadelphia	....	27,000
Antimony, value at San Francisco .... short tons..	35	7,000
Platinum, value, crude, at New York City.. troy ounces..	50	100
Total	....	215,364,825

a Including copper from imported pyrites.

Non-metallic mineral products of the United States in 1886 (*spot values*).

	Quantity.	Value.
Bituminous coal, brown coal, lignite, and anthracite mined elsewhere than in Pennsylvania *a* .... long tons..	65,810,676	$78,481,056
Pennsylvania anthracite *b* .... do.....	34,853,077	76,119,120
Lime .... barrels..	42,500,000	21,250,000
Petroleum .... do.....	28,110,115	20,028,457
Building stone	....	19,000,000
Natural gas	....	9,847,150
Salt .... barrels..	7,707,081	4,736,585
Cement .... do.....	4,500,000	3,990,000
Limestone for iron flux .... long tons..	4,717,163	2,830,297
South Carolina phosphate rock .... do.....	430,549	1,872,936
Zinc white .... short tons..	18,000	1,440,000
Mineral waters .... gallons sold..	8,950,317	1,284,070
Concentrated borax .... pounds..	9,778,290	488,915
Gypsum .... short tons..	95,250	428,625
New Jersey marls .... do.....	800,000	400,000
Ocher .... do.....	15,800	285,000
Manganese ore .... long tons..	30,193	277,636
Pyrites .... long tons..	55,000	247,500
Bromine .... pounds..	428,334	141,350
Flint .... long tons..	30,000	120,000
Corundum .... short tons..	645	116,190
Precious stones	....	79,056
Sulphur .... short tons..	2,500	75,000
Feldspar .... long tons..	14,900	74,500
Mica .... pounds..	40,000	70,000
Crude barytes .... long tons..	10,000	50,000
Gold quartz, souvenirs, jewelry, &c	....	40,000
Cobalt oxide, including ore and matte	....	36,878
Graphite .... pounds..	415,525	33,242
Slate ground as pigment .... long tons..	3,000	30,000
Chrome iron ore .... do.....	2,000	30,000
Fluorspar .... short tons..	5,000	22,500
Novaculite .... pounds..	1,160,000	15,000
Asphaltum .... short tons..	3,500	14,000
Asbestus .... do.....	200	6,000
Rutile .... pounds..	600	2,000
Total	....	243,963,063

a The commercial bituminous coal, excluding that consumed at the mines, was only 63,380,119 long tons, valued at $75,554,629.

b The commercial anthracite coal was only 32,764,710 long tons, valued at the sum of $71,558,126.

Résumé of the values of metallic and non-metallic substances produced in the United States in 1886.

Metals	$215,364,825
Mineral substances named in the foregoing table	243,963,063
	459,327,888
Estimated value of mineral products unspecified	6,000,000
Grand total	465,327,888

MISCELLANEOUS.

Both microscopic and macroscopic studies of the crystalline rocks are essential to the progress of certain lines of work and such studies are made in the petrographic laboratory. In response to the constant requirements of the different geologists of the Survey whose work is of such character as to demand careful rock examination the laboratory has executed much work during the year. A part of its force is employed in the preparation of slides for microscopic study &c. and the necessary laboratory apparatus is maintained for that purpose. During the year an important improvement in petrographic laboratory methods has been made: Heretofore the larger rock specimens have been sawed by means of metallic disks rotated at high velocity and fed with emery powder &c., but it has been found that the hardest rocks can be much more readily and economically sawed by means of a slender copper or soft iron wire, rapidly driven over pulleys and supplied with abrasive material. The efficiency of this part of the laboratory apparatus is greatly increased by this apparently slight improvement. The details of the work of the laboratory are set forth in the accompanying report of Mr. Diller.

The forest resources of the country are of great commercial importance and the forests themselves are important as factors affecting the drainage, freshets, water supply, &c. over considerable areas of the country. The operations of the Survey are such that information concerning certain forests and forestry can be collected at trifling labor and expense and provision has been made for so doing. In an accompanying administrative report Mr. Shutt sets forth the methods he has pursued in the work of this division.

COLLATERAL INVESTIGATIONS.

NATURAL GAS.

Since the commencement of the present decade a newly discovered mineral resource of great importance to the country has attracted widespread attention and in consequence of its application new industries have grown up and certain old industries have been modified. The discovery of large quantities of natural gas and its utilization in Western Pennsylvania five or six years ago were rapidly followed by discoveries in Ohio, and, as the official geologic surveys of these States investigated the deposits in which and the conditions under which natural gas may be found, rules for the guidance of exploitation in new fields were developed and field after field was opened, not only in these States, but also in New York, West Virginia, Kentucky, Indiana, Illinois, Iowa, Kansas, and Wyoming Territory, and natural gas is now extensively utilized in most of these States as a fuel and in some cases as an illuminant. Its employment as a fuel in certain manufactures (e. g., of iron and glass) has not only materially reduced the cost of manufacture, but has greatly improved the quality of the products, and the utilization of the same substance as a fuel for domestic purposes in several industrial centers has not only diminished the cost of living, but has promoted cleanliness and order.

Many geologists and engineers who have studied the subject of natural gas are of opinion that the present generation will see a decline in the output of the fields already exploited and that a few generations hence the supply will be practically exhausted throughout the entire country. But the same investigators are also of opinion that as the supply of natural gas fails an artificial product will be substituted for it and that new and improved methods for the manufacture of artificial gases to supply the place of the natural substance will be devised, and accordingly that the benefits resulting from the utilization of rock gas throughout the country will be permanent.

Realizing the importance of this new resource, the Geological Survey has taken part during the past year in investigations relating to it.

In Kansas, investigations of the gas field in the southeastern portion of the State have been carried on by Mr. Robert Hay in connection with his specific duty of elucidating the geologic structure of the tract, and the formations in which and the conditions under which rock gas may be found have been set forth not only through the public press but in a special memoir published under State auspices during last winter. In Ohio and Indiana investigations have been carried forward energetically by the official geologist of the former State, Prof. Edward Orton, and the Geological Survey has co-operated with him as far as seemed necessary. The various conditions under which rock gas occurs have been investigated by Professor Orton more fully than has hitherto been done in any country and a significant relation between the chemic constitution of the rock and the yield of gas has been established. This discovery promises to afford a key by which the difficult questions relating to gas distribution may be solved in such manner that the occurrence of the substance in specific localities may be much more surely predicted than heretofore.

Professor Orton has already published two preliminary reports on this subject under State auspices; but since their preparation he has collected much new and valuable information, which has been carefully collated and discussed and now forms one of the special papers accompanying this report.

THE CHARLESTON EARTHQUAKE.

The earthquake of August 31, 1886, by which a part of the city of Charleston was destroyed and nearly a hundred of her people killed, was not only one of the most appalling and lamentable catastrophes of this character occurring during the century, but was in many respects one of the most noteworthy seismic disturbances ever recorded. With two or three exceptions the area affected was greater than that of any other known earthquake; and, by reason of the general distribution not only of population but of fairly trustworthy chronometers and telegraphic communication over nearly the whole of this area and

by reason of the general employment of standard time, the opportunities afforded for systematic study of the phenomena were unexampled.

The shock, which was experienced at Washington, was recorded as carefully as possible, and, as soon as intelligence concerning its disastrous effects at Charleston and other southern cities reached the office of the Survey, steps were immediately taken to secure all possible data concerning it. Mr. Hayden, of the volcanic division, immediately sent out large numbers of circulars requesting information, these requests being so worded as to elicit data of the greatest possible value in systematic investigation. The data thus secured are extensive and voluminous, and much additional information was obtained through the United States Signal Service, the Light House Board, and other bureaus of the Government. The Survey also is under great obligations to the various gentlemen of the press throughout the country for their valuable contributions to the available fund of information concerning the catastrophe.

For the purpose of securing more definite information than could be otherwise obtained, Mr. McGee went to Charleston as soon as communication was reopened and secured a number of photographs and sketches, representing the effects of the earthquake upon structures, which afford means for ascertaining and comparing the intensity of action in different parts of the area affected. In addition, some significant notes were made upon the slighter secondary shocks, which continued for some weeks after the initial disturbance, and upon the detonations by which nearly all of them were accompanied. Arrangements were also made by Mr. McGee to have these local studies continued in accordance with what seemed the most promising plans. This work was done in an eminently satisfactory manner by Mr. Earle Sloan, a mining engineer and resident of Charleston. Mr. Sloan's operations were hastily conducted and circumstances prevented him from devoting adequate time to the preparation of a systematic report, but the record which he transmitted to the office of the Survey is to be ranked among the most valuable accounts of seismic phenomena ever written.

On the return of Captain Dutton from the field of his summer's labors in Oregon, he undertook the laborious task of reducing and systemizing the vast number of observations recorded in circulars, notes, press accounts, and correspondence, of thoroughly digesting the voluminous data, and of setting forth the results of his investigations as a contribution to the science of seismology. After assembling and fully digesting the records, Captain Dutton also visited Charleston and Summerville and not only collected much additional information, but verified certain important inferences based upon the data already in hand.

Rapid progress has been made in the discussion of the data secured from these various sources and in the preparation of a monograph on the subject. This report will soon be ready for the press.

RESEARCHES IN TERRESTRIAL PHYSICS.

During the year Messrs. Barus and Hallock, of the division of chemistry and physics, have continued their investigations into the properties of solid substances under varying conditions. Questions as to the nature of viscosity and the influence of the viscosity of rocks upon orogeny and the movements of the terrestrial crust generally are of fundamental importance in certain lines of geologic research, and the investigations of the year have thrown much light upon the subject and have resulted in the determination of certain coefficients of viscosity and of the relations of this property of substances to certain other properties. Preliminary results of their work have already been made public through a bulletin of the Survey.

The general subject of terrestrial physics which has been thus experimentally approached in one division of the Survey has been approached from a different direction in another division. During the year Mr. Woodward has continued his researches on the sea level as affected by the attraction of adventitious masses, described in the last report, and has also mathematically investigated the probable rate of the secular cooling of the earth and the effects of such cooling upon terrestrial contraction, as well as upon the distribution of internal temperatures. He has also investigated the probable distribu-

tion of density and pressure within the earth and the relations of these factors to temperature; he has similarly investigated the stresses of the terrestrial crust and considered their relations to antecedent and consequent deformations of the terrestrial crust. A part of the results of these investigations will be made public in monographs now in course of preparation and a part will form the subjects of bulletins now ready for the press.

FINANCIAL STATEMENT.

Amounts appropriated for and expended by the United States Geological Survey for the fiscal year ending June 30, 1887.

		Geological Survey.	Salaries, office of Geological Survey.	Total appropriation.
Amounts appropriated		$467,700.00	$35,540.00	$503,240.00
Amounts expended, classified as follows:				
Expenses.				
A. Services	$349,836.93			
B. Traveling expenses	20,342.77			
C. Transportation of property	4,273.10			
D. Field subsistence	7,989.30			
E. Field supplies and expenses	39,503.49			
F. Field material	9,637.36			
G. Instruments	6,179.41			
H. Laboratory material	4,294.08			
I. Photographic material	3,558.94			
K. Books and maps	3,920.60			
L. Stationery and drawing material	808.94			
M. Illustrations for reports	1,086.00			
N. Office rents	2,409.44			
O. Office furniture	680.06			
P. Office supplies and repairs	5,304.27			
Q. Storage	577.88			
R. Correspondence	344.13			
S. Bonded railroad accounts: Freight, $659.57; transportation of assistants, $1,494.05	2,153.62	462,900.32		
Salaries.				
A. Salaries			34,980.94	497,881.26
Balance unexpended		4,799.68	559.06	5,358.74
Probable amount required to meet outstanding liabilities		4,799.68		

ACKNOWLEDGMENTS.

As during previous years, the Survey is deeply indebted to the honorable the Secretary of the Interior for constant courtesy and consideration and for all possible facilities in the prosecution of the work of the Survey.

No less profound obligations are due to the Secretary of the Smithsonian Institution, Prof. Spencer F. Baird, for the use of laboratory rooms in the National Museum, for the care and suitable exhibition of the voluminous collections placed in his hands from time to time, and for his constant co-operation in the application of the principles of the museum system described in preceding pages of this report.

The railroads of the United States have with great liberality continued to facilitate the work of the Survey, not only by affording free transportation, but by furnishing records of their own surveys, which are of great service in the prosecution of topographic work, and it is a pleasure to express the obligations of the Survey to them for the assistance so courteously given.

It is with renewed gratification that the Director expresses his appreciation of the cordial co-operation, assistance, and consideration constantly received from the gentlemen whose work is under his supervision.

DEPARTMENT OF THE INTERIOR, UNITED STATES GEOLOGICAL SURVEY.

ADMINISTRATIVE REPORTS

OF

CHIEFS OF DIVISIONS

AND

HEADS OF INDEPENDENT PARTIES,

ACCOMPANYING THE ANNUAL REPORT OF THE

DIRECTOR OF THE U. S. GEOLOGICAL SURVEY

FOR THE

FISCAL YEAR ENDING JUNE 30, 1887.

ADMINISTRATIVE REPORTS.

REPORT OF MR. HENRY GANNETT.

DEPARTMENT OF THE INTERIOR,
U. S. GEOLOGICAL SURVEY,
DIVISION OF GEOGRAPHY,
Washington, D. C., July 1, 1887.

SIR: I have the honor to submit the following report upon the operations of the Division of Geography during the fiscal year ending June 30, 1887:

Geographic work was carried on in all the areas occupied during the year before, with the exception of the Yellowstone Park, which had been completed in the preceding autumn. These regions are as follows: Massachusetts, New Jersey, the region adjacent to the District of Columbia, the Appalachian mountains south of Mason and Dixon's line, Kansas, Missouri, Texas, Arizona, the gold belt of California, and the Cascade range of southern Oregon. In addition to these areas, work was commenced in southern Montana. The total area surveyed during the fiscal year is 55,684 square miles, distributed as follows:

Region.	Scale of field work.	Scale of publication.	Contour interval.	Area surveyed.
				Square miles.
Massachusetts	1: 30,000	1: 62,500	20	3,200
New Jersey	1: 20,000	1: 62,500	10 and 20	1,340
District of Columbia (adjacent area)	1: 30,000	1: 62,500	20	275
Appalachian	1:126,720	1:125,000	100	19,054
Missouri	1: 63,360	1:125,000	50	4,500
Kansas	1: 63,360	1:125,000	50	5,940
Texas	1:126,720	1:125,000	50	4,430
Arizona	1:126,720	1:250,000	200	7,620
California (gold belt)	1: 63,360	1:125,000	100	3,025
Oregon	1:126,720	1:250,000	200	3,000
Montana	1:126,720	1:250,000	200	3,300
Total				55,684

The survey of this area has enabled us to complete 67 sheets of the general topographic atlas.

ORGANIZATION.

At the beginning of the fiscal year certain changes were made in the form of organization. The work on the one-mile scale carried on in the area adjacent to the District of Columbia was transferred from the Appalachian section to the Northeastern section; otherwise these two sections remained as heretofore. The scope of the Western section was reduced by taking from it the work done in Kansas and Missouri, and constituting this, with such other work as may hereafter be done in the States of the Mississippi valley, a separate section, under the name of the Central section, which was placed under the charge of Mr. John H. Renshawe, geographer. Beyond the addition to the Western section of a subsection in Montana, which is substantially an extension of the work in the Yellowstone National Park, there has been no further change in organization. The principal changes in the personnel of the various sections and subsections are noted in treating of the work in detail.

NORTHEASTERN SECTION.

Massachusetts subsection.—At the opening of the fiscal year work was in active progress in this subsection. The party under Mr. E. W. F. Natter, comprising Messrs. J. H. Jennings, W. H. Hunter, C. D. Hepburn, and two field assistants, was at work upon the Framingham sheet. With this party Mr. Natter worked continuously throughout the season, closing field work practically at the end of November. He completed the Framingham sheet and surveyed the Lowell, Lawrence, Cape Ann, Salem, and Boston Bay sheets and the part of the Haverhill sheet lying in Massachusetts, besides adding some work on the Dedham sheet. Early in May of the present year his party, which was similar in organization to that of the year before, resumed work, completing the unfinished portions of the Dedham sheet and commencing work on the Groton sheet.

At the commencement of the fiscal year Mr. W. D. Johnson had in the field four plane tablers, viz, Messrs. R. D. Cummin, W. H. Lovell, C. C. Bassett, and H. L. Smyth, who were at work upon the Becket, Sandisfield, Chesterfield, and Granville sheets. Two plane tablers were subsequently added to his force, viz, Messrs. Louis F. Cutter, of the Massachusetts Institute of Technology, and George H. Page, of Harvard. Work was prosecuted continuously with this force until the end of the season, one of the plane tablers leaving the field in November, four others in December, while the sixth continued work for a few days in January. These men completed the Becket, Sandisfield, and Chesterfield sheets and very nearly finished the Hawley and Granville sheets, besides making a commencement upon the Marlborough sheet. As the office work of the different members of

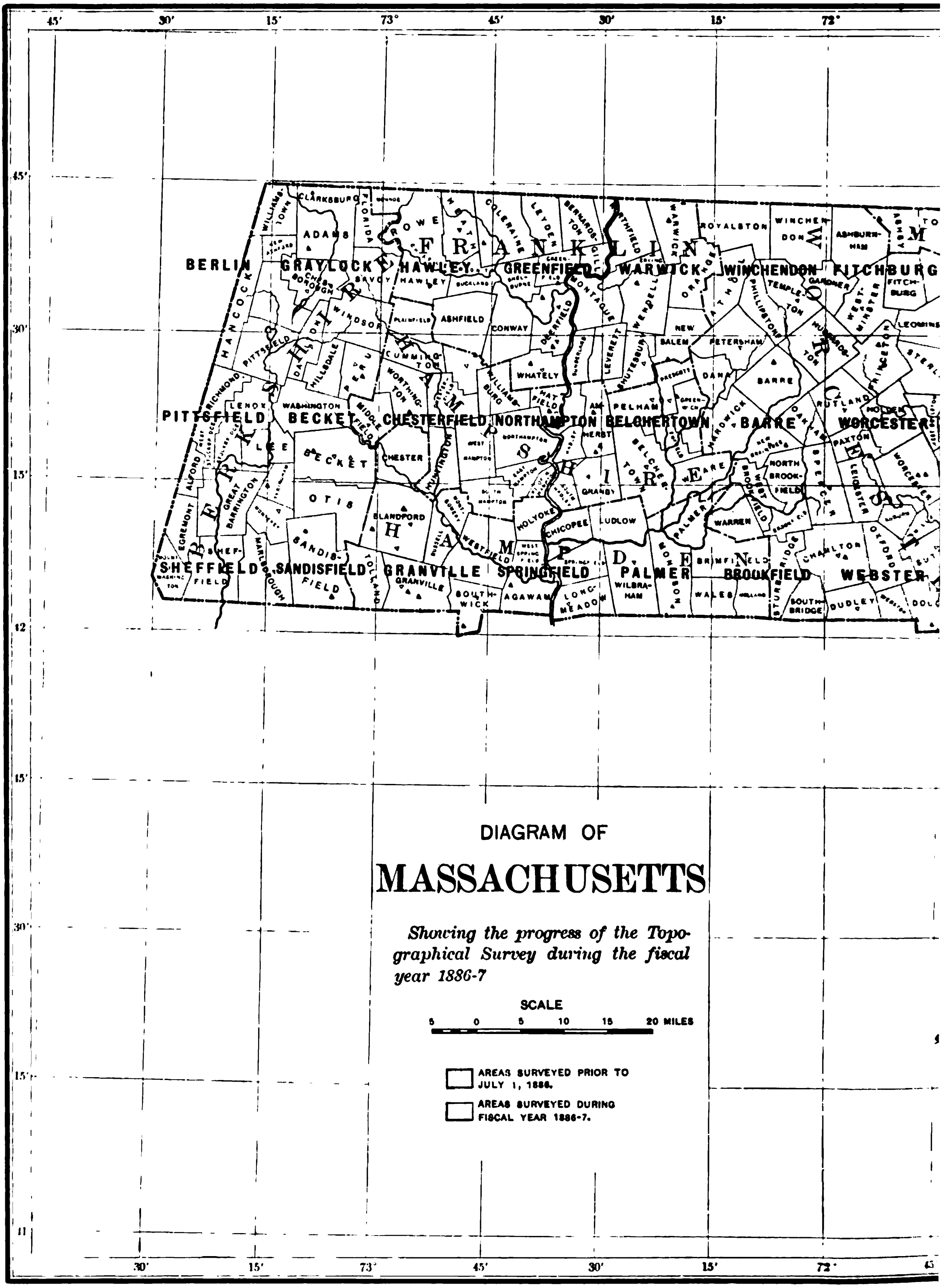
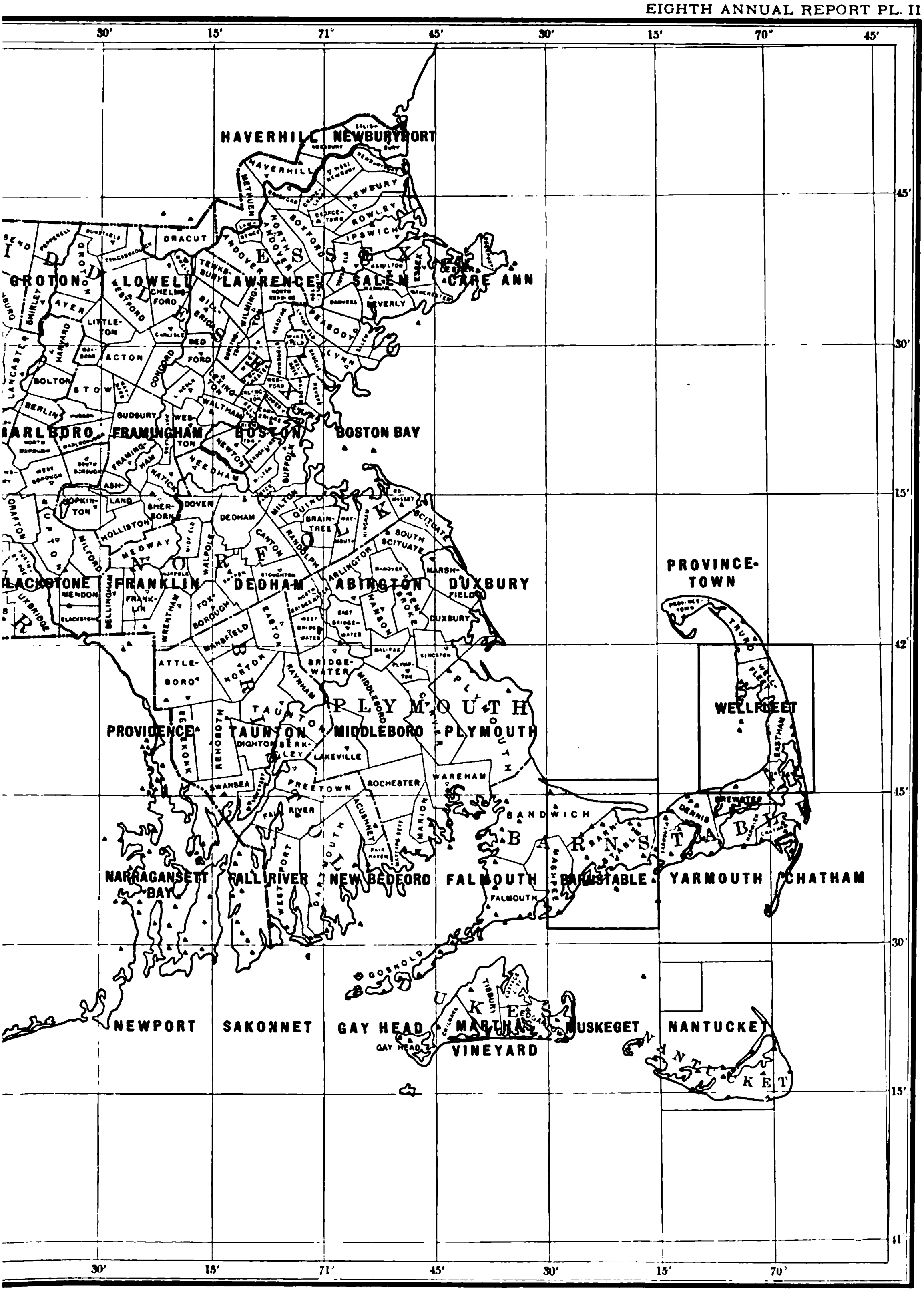


DIAGRAM OF
MASSACHUSETTS
Showing the progress of the Topographical Survey during the fiscal year 1886-7
SCALE
5 0 5 10 15 20 MILES
AREAS SURVEYED PRIOR TO JULY 1, 1886.
AREAS SURVEYED DURING FISCAL YEAR 1886-7.
BERLIN
GRAYLOCK
HAWLEY
GREENFIELD
WARWICK
WINCHENDON
FITCHBURG
PITTSFIELD
BECKET
CHESTERFIELD
NORTHAMPTON
BELCHERTOWN
BARRE
WORCESTER
SHEFFIELD
SANDISFIELD
GRANVILLE
SPRINGFIELD
PALMER
BROOKFIELD
WEBSTER



Giles Lith. & Liberty Ptng. Co. N. Y.

this party was completed in the spring, they resumed field work, Messrs. Cummin, Lovell, and Bassett leaving for the field about the middle of May and Mr. Smyth early in June.

Upon the resumption of field work, Mr. Cummin continued the survey of the Marlborough sheet, Mr. Lovell continued to completion the Hawley sheet, and Mr. Bassett completed the Granville sheet and extended his work eastward into the Springfield sheet, while Mr. Smyth was engaged in filling up certain gaps upon the southern half of the Hawley sheet, which formed a part of his work of the season before.

At the beginning of the fiscal year, Mr. Sumner H. Bodfish had in the field Messrs. Laurence Thompson, E. B. Clark, Clifford Arrick, Van H. Manning, jr., and S. A. Aplin, jr., with the requisite rodmen. At the close of September Mr. Aplin was detailed to the office. With this exception the work was prosecuted during the season with this force, closing in the early part of December. The areas surveyed included the southern portion of Cape Cod, which, with the aid of the Coast and Geodetic Survey work, nearly completed the cape. The Duxbury, Abington, Franklin, and Blackstone sheets, which had been in part surveyed before, were completed, with the exception of certain bits requiring additions and revision. The Dedham sheet was nearly finished and the northern halves of the Webster and Franklin sheets were surveyed, together with certain areas in the eastern part of the Springfield and western part of the Palmer sheets.

During the month of May of the present field season, Mr. Bodfish was ordered to Massachusetts, with instructions to make certain revisions and additions in areas reported as completed. Mr. Clark was sent to Cape Cod for the purpose of completing the unfinished area in that region and Mr. Arrick for the purpose of continuing work upon the eastern portion of the Springfield sheet and upon the Palmer sheet; early in June Mr. Laurence Thompson was transferred to Mr. Johnson's party, with instructions to continue the survey of the Belchertown sheet, which had been commenced by Mr. Anton Karl two years before.

Mr. Karl began field work August 17 and closed November 29. He had at first two assistants, later only one, and during the last few days none. He surveyed three-fourths of the Greenfield sheet, on the southern half of which considerable traverse work had been done during the previous season.

The entire area surveyed by the parties in Massachusetts during the fiscal year is 3,200 square miles. (See Plate II.)

Upon the completion of their office work, Messrs. W. J. Grambs, Louis F. Cutter, and George H. Page, of the Massachusetts subsection, resigned.

New Jersey subsection.—This subsection has continued under the

charge of Prof. George H. Cook, geologist. Triangulation and topographic work have been actively prosecuted during the year. At its opening, there remained an area of 1,000 square miles, in Atlantic, Salem, and Cumberland counties, which had never been covered by a triangulation. Besides supplying control in this area, it seemed desirable to secure additional points in areas already surveyed in Hunterdon, Middlesex, and Union counties. This work of extending the triangulation was carried on by Mr. C. C. Vermeule, topographer in charge, and Prof. A. A. Titsworth, assisted by Mr. John E. Hill; altogether 59 points were located during the season.

In the prosecution of topographic work there were employed Messrs. F. W. Bennett, P. H. Bevier, W. H. Luster, jr., P. D. Staats, and Asher Atkinson, with their aids, making in all ten men engaged in leveling, securing topographic details, and sketching contours in the counties of Hunterdon, Middlesex, Salem, Atlantic, and Cumberland. Messrs. H. B. K. Hoffman and W. F. Marvin were engaged in traversing with odometers in the same districts. In the course of this work a careful survey was made of a portion of the Delaware river which had not been surveyed in previous years, thus completing an accurate plat of the boundaries of the State. Field work closed December 10, when an area of 1,340 square miles had been completed and an additional area of 104 square miles traversed. During the winter Mr. Vermeule and his assistants were engaged in platting in the office at New Brunswick.

The work of this year substantially completes the State, a small amount of work only remaining, which consists in the examination and verification of certain old surveys in the northeastern part, the running of certain lines of primary levels, the establishment of bench marks, etc. This work will be finished early in the coming fiscal year and at slight expense.

New Jersey is the first of the States to obtain an accurate topographic map of its entire area.

District of Columbia subsection.—The survey of the two atlas sheets which include the District of Columbia and adjacent territory was continued by a small force during the past fiscal year. At the beginning of the fiscal year, Mr. D. J. Howell, with a rodman, had completed the western sheet, with the exception of the area lying within the District of Columbia. This area, being under survey jointly by the U. S. Coast and Geodetic Survey and the Commissioners of the District of Columbia, was temporarily left, with the expectation that it could be completed by a compilation from their maps. During the season Mr. Howell completed the survey of the eastern sheet and during the winter and spring platted the work and completed the drawing and compilation, besides executing a small amount of field work in the western part of the District, for the purpose of finishing the sheet. The area surveyed by Mr. Howell during

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the field season is 275 square miles. It has been done entirely by telemeter.

APPALACHIAN SECTION.

This section has been, as heretofore, in charge of Mr. Gilbert Thompson, geographer.

The work was carried on during the past season by one triangulation party, under Mr. S. S. Gannett, and seven topographic parties, respectively under Messrs. W. T. Griswold, Louis C. Fletcher, Morris Bien, Fred. J. Knight, Frank M. Pearson, Charles M. Yeates, and Louis Nell, and, in addition to these, independent work was for a time carried on by Mr. Merrill Hackett.

At the beginning of the fiscal year Mr. Gannett was in the field at work with one assistant, extending the triangulation west of the Appalachian belt and north of the transcontinental belt of the Coast and Geodetic Survey. His work in this field was continued until October, when, the weather becoming unfavorable, he was directed to discontinue work and report in Washington. During the season he occupied twelve stations.

The party under Mr. Griswold was in the field at work prior to July 1 in the Blue Ridge and the region east of it. As assistants Mr. Griswold had Messrs. E. C. Barnard, C. G. Van Hook, S. H. Giesy, G. L. Johnson, and J. D. Lincoln. During the fiscal year this party mapped 2,650 square miles, including a part of the Blue Ridge and the Atlantic plain as far east as the Potomac river and south to the Great Falls of the Potomac. It was disbanded at Warrenton, Va., October 31, 1886.

Mr. Fletcher was given an independent party at the beginning of the season and outfitted at Harrisonburg, Va., July 6. As his assistants there were detailed Messrs. R. O. Gordon, W. J. O'Connell, R. H. Hooe, E. G. Kennedy, and H. S. Selden. His field of work lay adjacent to and south of the field of work of his subparty during the season before, including the heads of Cheat river and the broken, mountainous country west of the Shenandoah valley, with a part of Augusta county, Va. This party mapped 2,800 square miles during the season. It was disbanded October 31, at Staunton, Va., but Mr. Fletcher, with two assistants, remained in the field until November 15, working in the Shenandoah valley.

The party under Mr. Bien was outfitted at Pearisburgh, Va., and commenced work August 11. He had as assistants Messrs. R. C. McKinney, C. E. Cooke, H. T. Irwin, Lawson Sanford, and C. H. Barnitz. His work consisted in the extension northeastward of his former surveys, and he mapped during the season 2,250 square miles. The party was disbanded at Covington, Va., October 31, 1886.

The party under Mr. Knight commenced work August 16. The

assistants in this party were Messrs. D. C. Harrison, R. M. Towson, L. D. Brent, C. W. Goodlove, W. M. Edelen, and M. J. Holt. In addition to topographic work this party was obliged to carry on triangulation; owing to the extremely unfavorable weather during the season, however, but little success attended this branch of the work. The party mapped 1,600 square miles in a most difficult region in southeastern Kentucky. It was disbanded at Williamsburg, Ky., November 8.

Mr. Pearson's party commenced work early in August, with Messrs. H. B. Blair, Arlington E. Murlin, H. B. Munroe, and C. J. Akin as assistants, and, on September 28, Mr. Merrill Hackett was added to the list. The field of work of this party was in northern Georgia. An area of 2,700 square miles was covered during the season. The party disbanded at Cartersville, Ga., November 10.

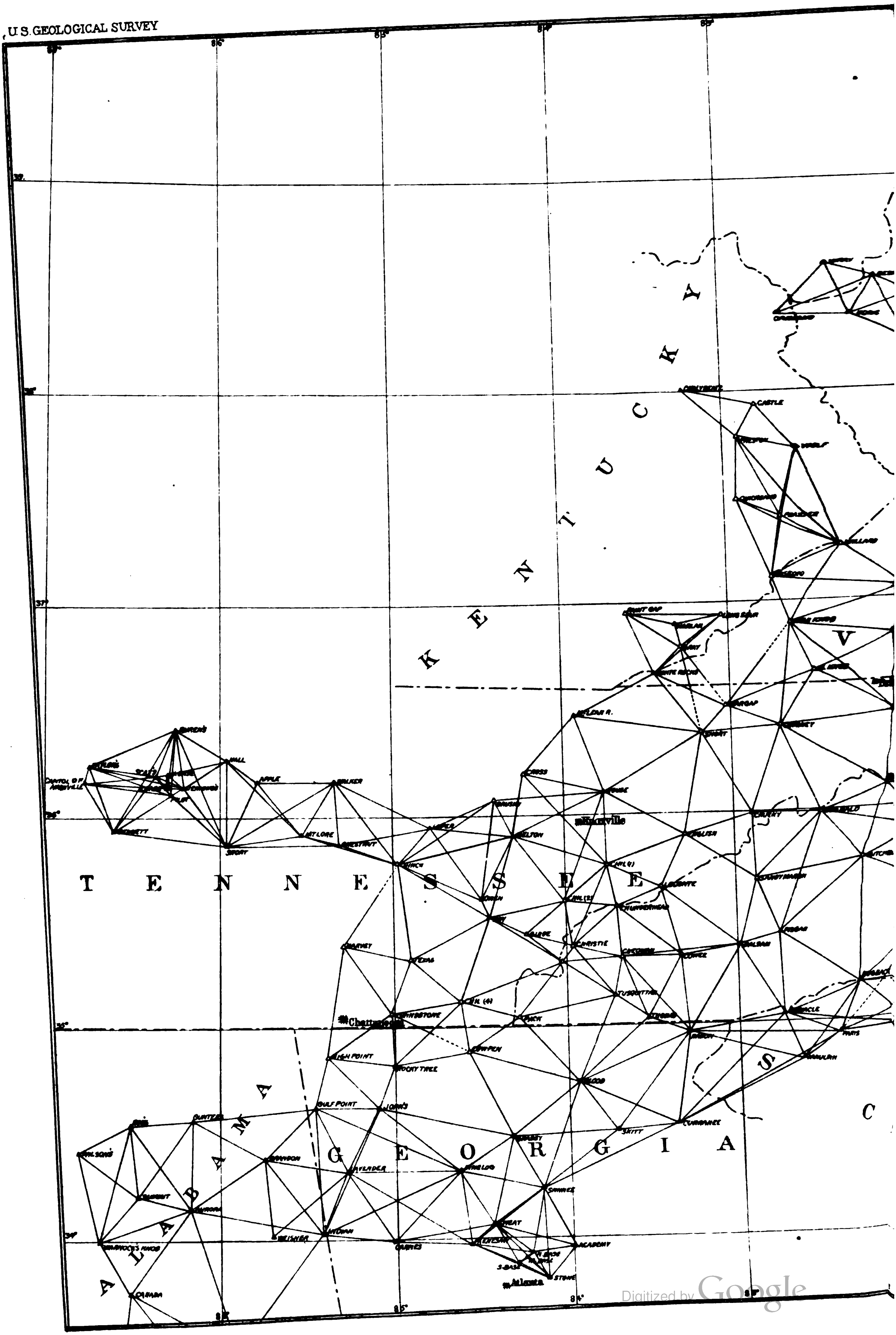
Mr. Yeates's party commenced work about the middle of August, with Messrs. J. W. Hays, R. L. Longstreet, W. L. Miller, R. McC. Michler, Desha and Robert Breckenridge, and R. H. Stuart as assistants. His field of work lay in the northwestern part of South Carolina and in North Carolina east of the Blue Ridge. This party mapped 4,100 square miles and disbanded at Lenoir, N. C., November 10.

Mr. Nell commenced work about the middle of August, with Messrs. Jere. Ahern, W. R. Atkinson, James Longstreet, jr., S. A. Foot, and F. P. Gulliver as assistants. His field of work was in northern Alabama, south of his area of the preceding season. He surveyed during the season 2,364 square miles and disbanded his party at Cartersville, Ga., November 10.

To Mr. Merrill Hackett was given the task of completing the Chattanooga atlas sheet, an area of 590 square miles, which he surveyed between July 17 and September 28.

For the reduction of the barometric work, base stations were established at Warrenton, Va., Lexington, Va., Roan Mountain, N. C., Richmond, Ky., and Spartanburgh, S. C. Wherever necessary, these base stations were connected by lines of spirit level with railroads. Through the courtesy of the Chief Signal Officer of the Army, the late General W. B. Hazen, the observations made at the signal stations at Chattanooga, Tenn., and Atlanta, Ga., were furnished and were utilized for the same purpose. Two cistern barometers were provided for each party, one of which was read in camp, the other being used upon stations.

The weather during the season was exceptionally favorable for the prosecution of work and only the shortness of the season prevented a larger output. The area surveyed by this section during the season is 19,054 square miles. The areas surveyed are represented upon the general map of progress (Plate I, in the pocket at the end of this volume).


K E N T U C K Y
T E N N E S S E E
G E O R G I A
A L A B A M A
V
C
Knoxville
Chattanooga
Atlanta

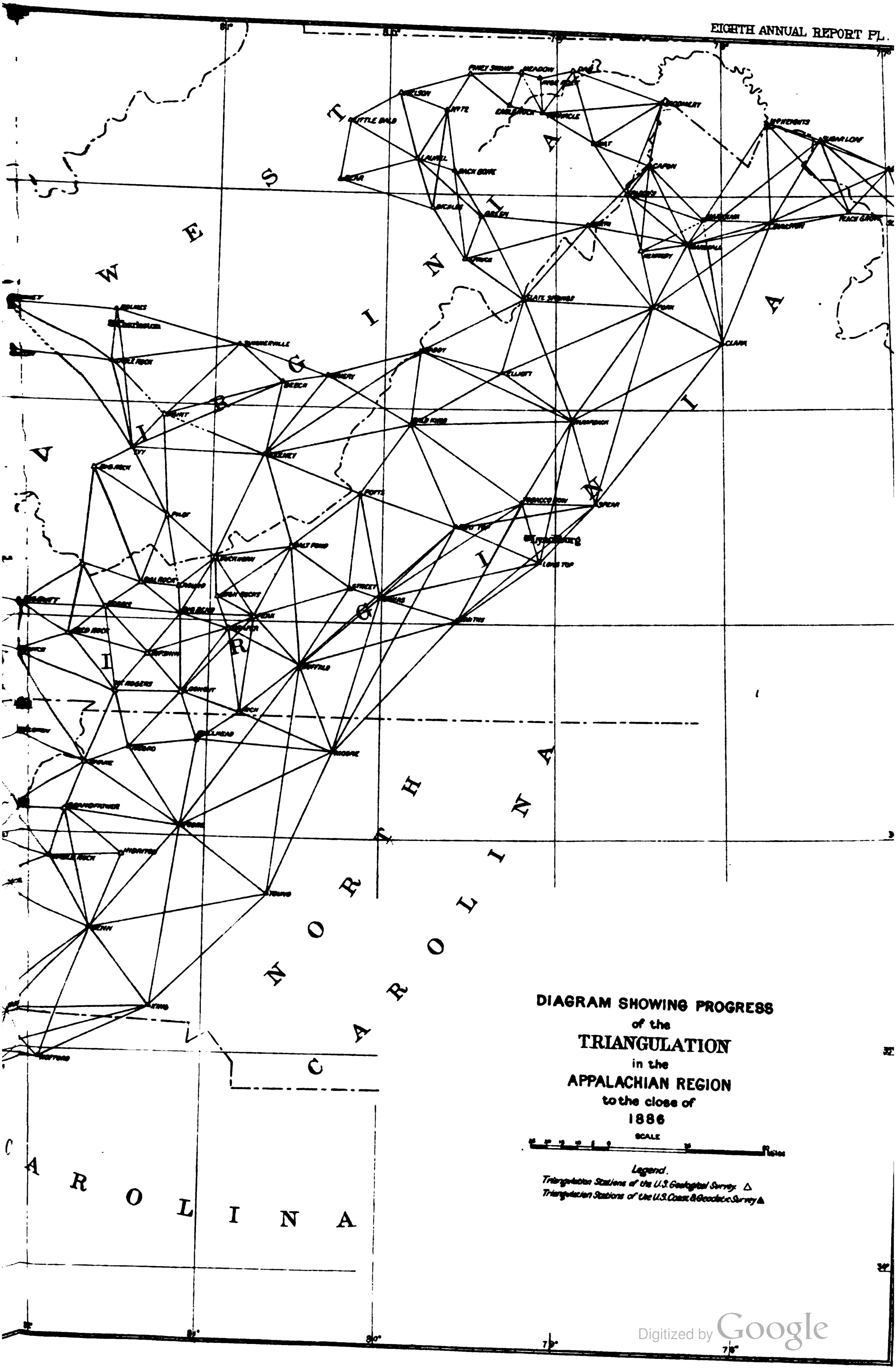


DIAGRAM SHOWING PROGRESS
of the
TRIANGULATION
in the
APPALACHIAN REGION
to the close of
1886

In March of the present year, Mr. Frank M. Pearson, topographer, who since 1882 had been in charge of one of the parties of this section, resigned to engage in other pursuits.

CENTRAL SECTION.

Upon the organization of the work in Kansas and Missouri as a separate section, in charge of Mr. J. H. Renshawe, geographer, Mr. R. U. Goode was transferred to the charge of the Texas subsection and Mr. E. M. Douglas, who had been in charge of the Texas subsection, was assigned to the Montana subsection.

The Kansas and Missouri parties were placed in the field early in July. The organization consisted of two topographic parties and one party for carrying on triangulation, which was under the immediate charge of Mr. Renshawe, while the two topographic parties were respectively under Messrs. H. L. Baldwin, jr., and W. J. Peters.

To Mr. Baldwin's party was assigned the task of surveying the square degree limited between latitudes 38° and 39° and longitudes 92° and 93°, together with an additional area lying south of the Missouri river, in central Missouri. The transcontinental belt of triangulation of the Coast and Geodetic Survey extends across the middle of this square degree, and its points, when connected with the land surveys, furnished adequate control, so that no other triangulation was needed for Mr. Baldwin's area. To Mr. Baldwin's party were assigned Mr. W. H. Herron and one rodman, and with this force he prosecuted work continuously until the end of October, having completed the area assigned him, estimated at 4,500 square miles.

To the party under Mr. Peters were assigned the unfinished portions of the square degrees lying between latitudes 39° and 40° and longitudes 95° and 97°. The southeastern part of this area was surveyed in 1885 by Mr. E. T. Perkins, jr. The area thus assigned to Mr. Peters comprised some 5,940 square miles. To his party were detailed as assistants Messrs. C. T. Reid and one rodman. He succeeded easily in completing the area assigned and the party was broken up early in November.

To Mr. Renshawe fell the duty of extending the triangulation over the area mapped by Mr. Peters's party. For this purpose he assumed as a base the line between the stations Eckman and Blue Mound, in the transcontinental belt of the Coast and Geodetic Survey, in eastern Kansas. From this line he extended triangulation, at first northwestward and then westward. in a series of triangles and quadrilaterals, to the neighborhood of the meridian of 97°. This belt involved the occupation of twenty-seven stations during the season. All these stations were connected with section corners of the land

surveys. At the western end of this belt Mr. Renshawe observed for azimuth, and then, proceeding to the western end of the belt measured by Mr. Goode during the preceding season, observed for azimuth upon its western line.

As a check upon the accuracy of these two pieces of triangulation I may mention the fact that connection was made by each with a point upon the first guide meridian west of the sixth principal meridian. The discrepancy in longitude between these two points was found to be less than half a second of arc, i. e., about 35 feet. The smallness of this discrepancy shows not only that the work is fully up to the required standard but that the azimuth of the guide meridian was excellent.

The entire area surveyed by this section during the season is 10,440 square miles.

WESTERN SECTION.

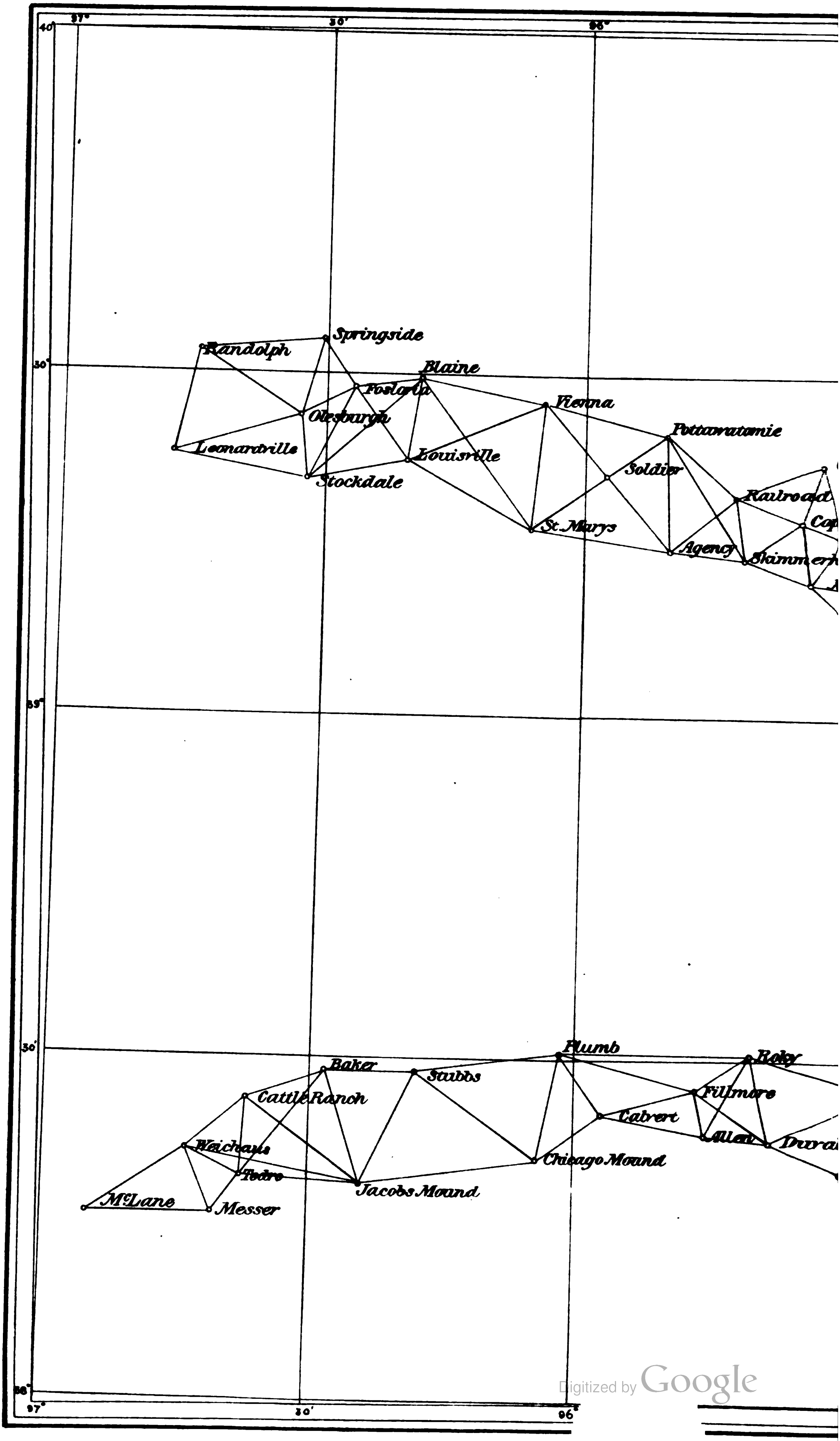
Texas subsection.—The organization of this work was similar to that of the season before, but there were some changes in personnel, Mr. R. U. Goode being placed in charge of the subsection and Messrs. C. H. Fitch and H. S. Wallace respectively in charge of the topographic parties. Triangulation had been prosecuted in this area for some six weeks prior to the beginning of the fiscal year by Mr. E. M. Douglas. When he was relieved by Mr. Goode a considerable part of the season's work had been laid out. Mr. Goode had as assistant Mr. C. F. Urquhart. In the extension of triangulation over the area to be surveyed Mr. Goode encountered difficulties due to the fact that the area consisted of a broad, plateaulike country, covered with forests. After several attempts to carry triangulation across this, he was finally obliged to give it up and to inclose the area by a belt of triangles. He occupied during the season 30 stations; his work was concluded and the party disbanded early in November.

Mr. Fitch, with two assistants, surveyed during the season, between the middle of July and the first of November, two atlas sheets and a part of a third.

Mr. Wallace's party consisted, besides himself, of two meander men and the necessary laboring force. This party surveyed two atlas sheets during the season.

The total area surveyed by this subsection during the season is 4,430 square miles.

Arizona subsection.—The work in Arizona was carried on, as during the previous season, by one party, under Mr. A. P. Davis. The area assigned to it comprised the two square degrees lying between latitudes 34° and 35° and longitudes 109° and 111°. Mr. Davis, with his assistant, Mr. Robert H. Chapman, commenced work about the middle of July, carrying on both triangulation and topography. A second assistant, for meandering, Mr. C. A. Garlick, was em-



40°
97°
30'
96°
Randolph
Springside
Blaine
Fostoria
Oleseburgh
Leonardville
Louisville
Stockdale
Vienna
Pottawatomie
Soldier
St. Marys
Agency
Railroad
Skimmer
39°
30'
Plumb
Roby
Baker
Stubbs
Cattle Ranch
Fillmore
Calvert
Weichaus
Allen
Chicago Mound
Tedro
Jacobs Mound
McLane
Messer
38°
97°
30'
96°

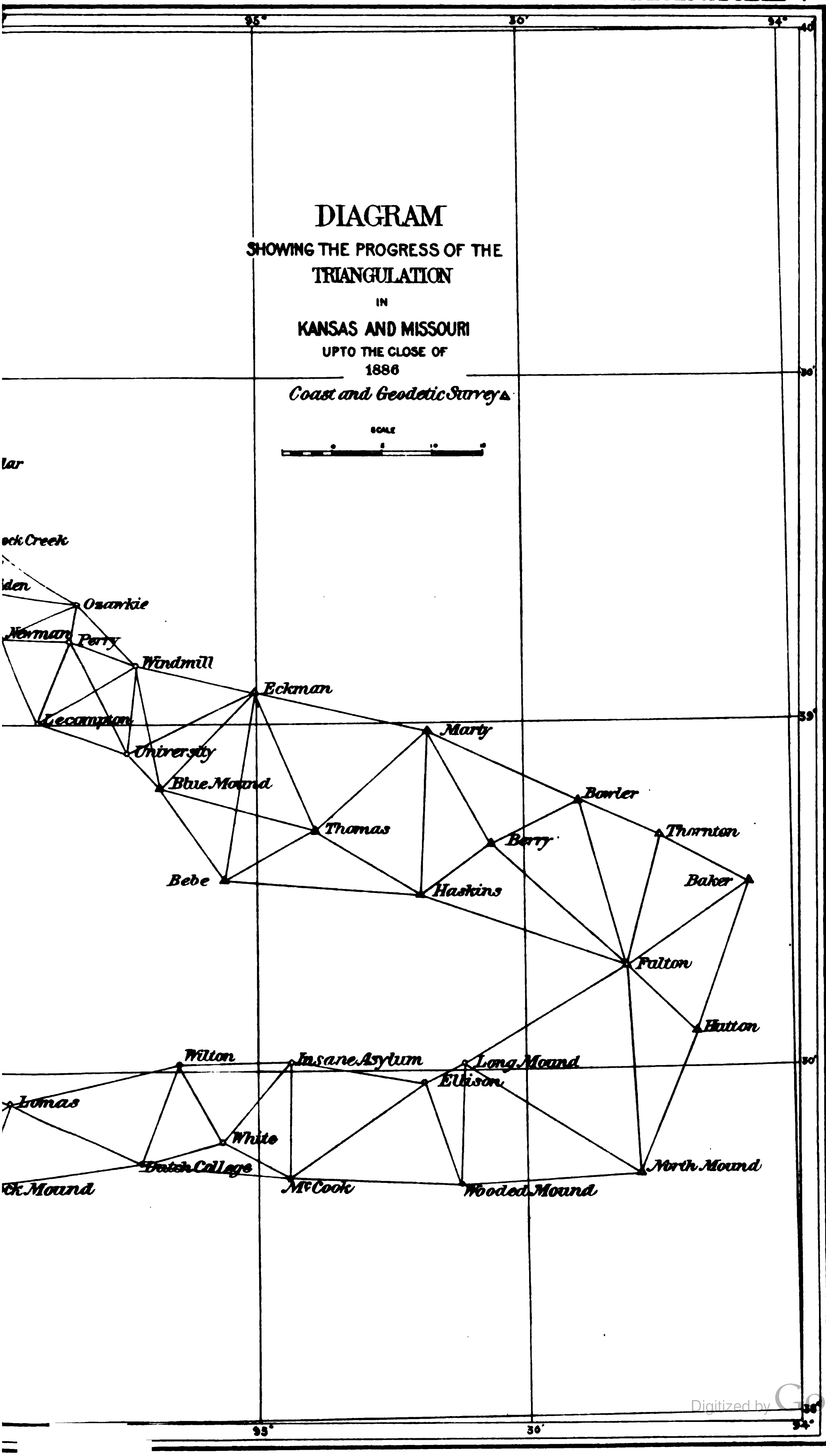


DIAGRAM
SHOWING THE PROGRESS OF THE
TRIANGULATION
IN
KANSAS AND MISSOURI
UPTO THE CLOSE OF
1886
Coast and Geodetic Survey
95°
30'
94°
40°
39°
Ozawkie
Newman
Perry
Windmill
Eckman
Lecompton
University
Blue Mound
Marty
Bowler
Thornton
Thomas
Berry
Baker
Bebe
Haskins
Falton
Hutton
Wilton
Insane Asylum
Long Mound
Ellison
Lomas
White
Dutch College
McCook
Wooded Mound
North Mound
95°
30'
94°
38°

ployed in Arizona. The party was so organized that it could be divided into two subparties, or even three, on occasion, as was frequently done. The area surveyed by this subsection is comprised in large part in the Colorado plateau and its southern slopes, the plateau itself being mainly a desert of comparatively level surface, while its slopes are rugged and mountainous. An area of 7,620 square miles was surveyed during the season and the party disbanded at Taylor, Ariz., in November.

Gold belt subsection.—The organization for the prosecution of the work was similar to that of the preceding season. Mr. H. M. Wilson remained in charge of it, while, in the place of Mr. Peters, who was transferred to the Central section, there was detailed Mr. A. F. Dunnington, from the Texas subsection. For two months prior to the beginning of the fiscal year Mr. Wilson, assisted by Mr. Peters, had been upon the ground, engaged in extending the primary triangulation and connecting it with that of the Coast and Geodetic Survey, and at the beginning of the fiscal year nearly all of the primary triangulation required for the control of the season's topography had been executed. The parties were organized during July and by the end of the month were at work. For a large part of the season Mr. R. H. McKee, with the requisite laboring force, was engaged upon independent work, thus making substantially three parties in the field. The area surveyed in this region during the season was extended southward to the thirty-ninth parallel and westward to the one hundred and twenty-second meridian, covering an area of 3,025 square miles.

Early in May of the present year Messrs. Wilson, Dunnington, and McKee were ordered again to the field, for the purpose of extending the triangulation during the spring months, while the atmospheric conditions were still favorable. Recent reports received from them indicate the successful prosecution of the work.

Oregon subsection.—This work, as heretofore, has been carried on by two parties, in charge, respectively, of Messrs. M. B. Kerr and Eugene Ricksecker. At the beginning of the fiscal year they were in the field engaged in extending triangulation. Immediately after July 1 the organization of the parties for the season was completed, and from that time forward work was prosecuted as continuously as atmospheric conditions would permit. The work was, however, sadly interfered with by smoke and haze, and the output of the season consisted of only 3,000 square miles. The parties were disbanded in October. Ten triangulation points were occupied during the season, several of which were peaks of the Cascade range, among them Mounts Pitt and Scott.

Montana subsection.—Three parties were organized in southwestern Montana for the purpose of prosecuting work, having in view publication upon a scale of 1: 250,000, with a contour interval of 200

feet. The work was placed in charge of Mr. E. M. Douglas, who conducted the primary triangulation, while Messrs. Frank Tweedy and W. H. Leffingwell were in charge of the topographic parties. The triangulation consisted in the extension of that executed by Mr. J. H. Renshawe and his assistants in 1883–'84, which rests upon the Bozeman base and upon the astronomic determination of Bozeman, Mont. The prevailing smokiness of the atmosphere interfered with the triangulation so that but nine stations were successfully occupied, but enough was done to control the topographic work.

The party under Mr. Tweedy completed the unsurveyed portion of the square degree lying between latitudes 45° and 46° and longitudes 111° and 112°, together with the western portion of the square degree lying east of it, aggregating about 3,000 square miles and comprising some of the heaviest mountain country of the Territory.

The party under Mr. Leffingwell was directed to undertake the sheet lying between latitudes 45° and 46° and longitudes 109° and 110°, an area lying almost entirely in the heart of the mountain region which separates the Big Horn from the Yellowstone river. Mr. Leffingwell labored under several difficulties, as he was late in getting into the field and lost much time in getting started upon his plane table work, owing to the fact that there were no points located by triangulation within fifty miles of his atlas sheet. As a result of this the area which was brought in at the close of the season was but trifling.

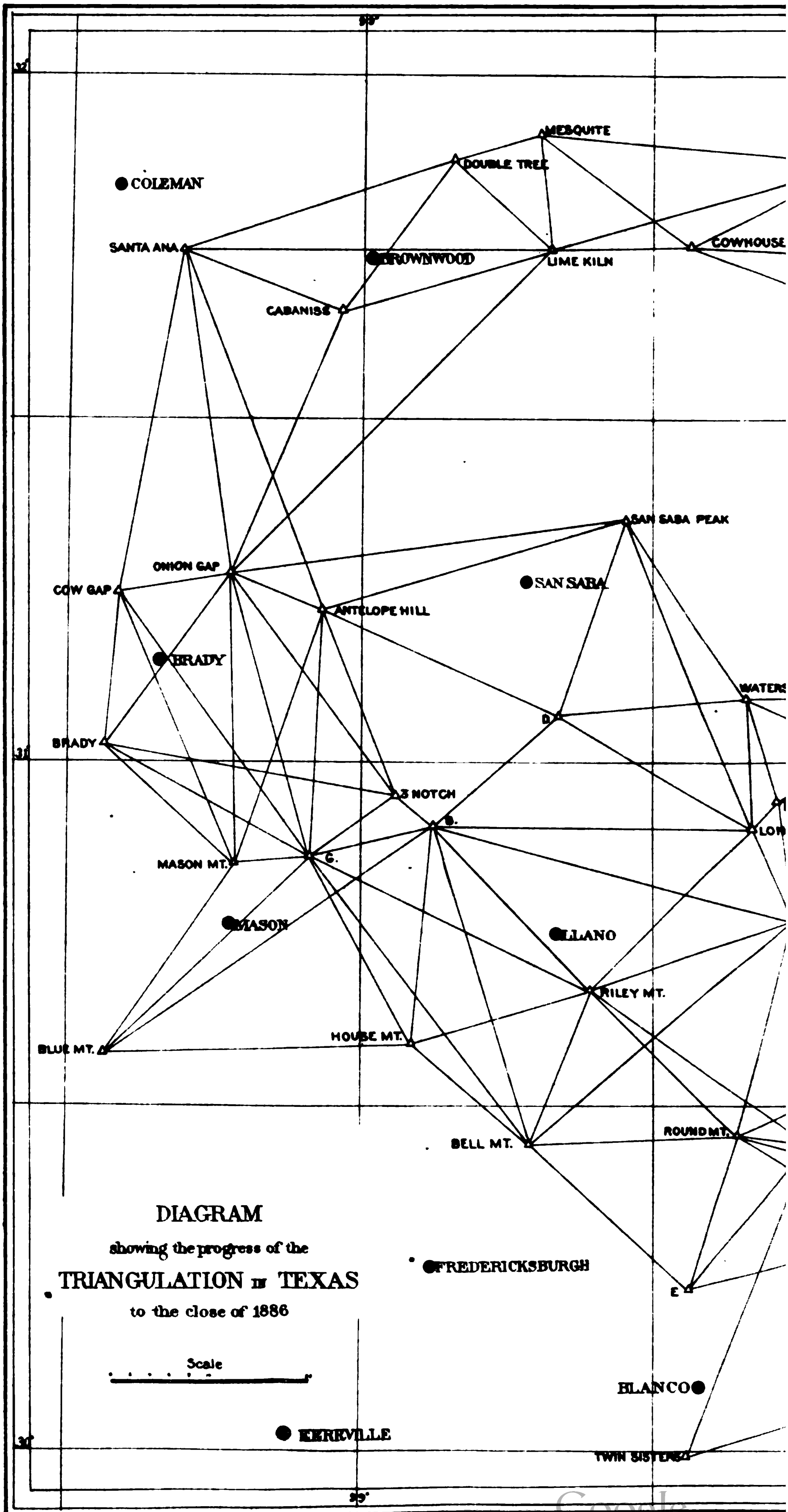
The total area surveyed by this section was 3,300 square miles.

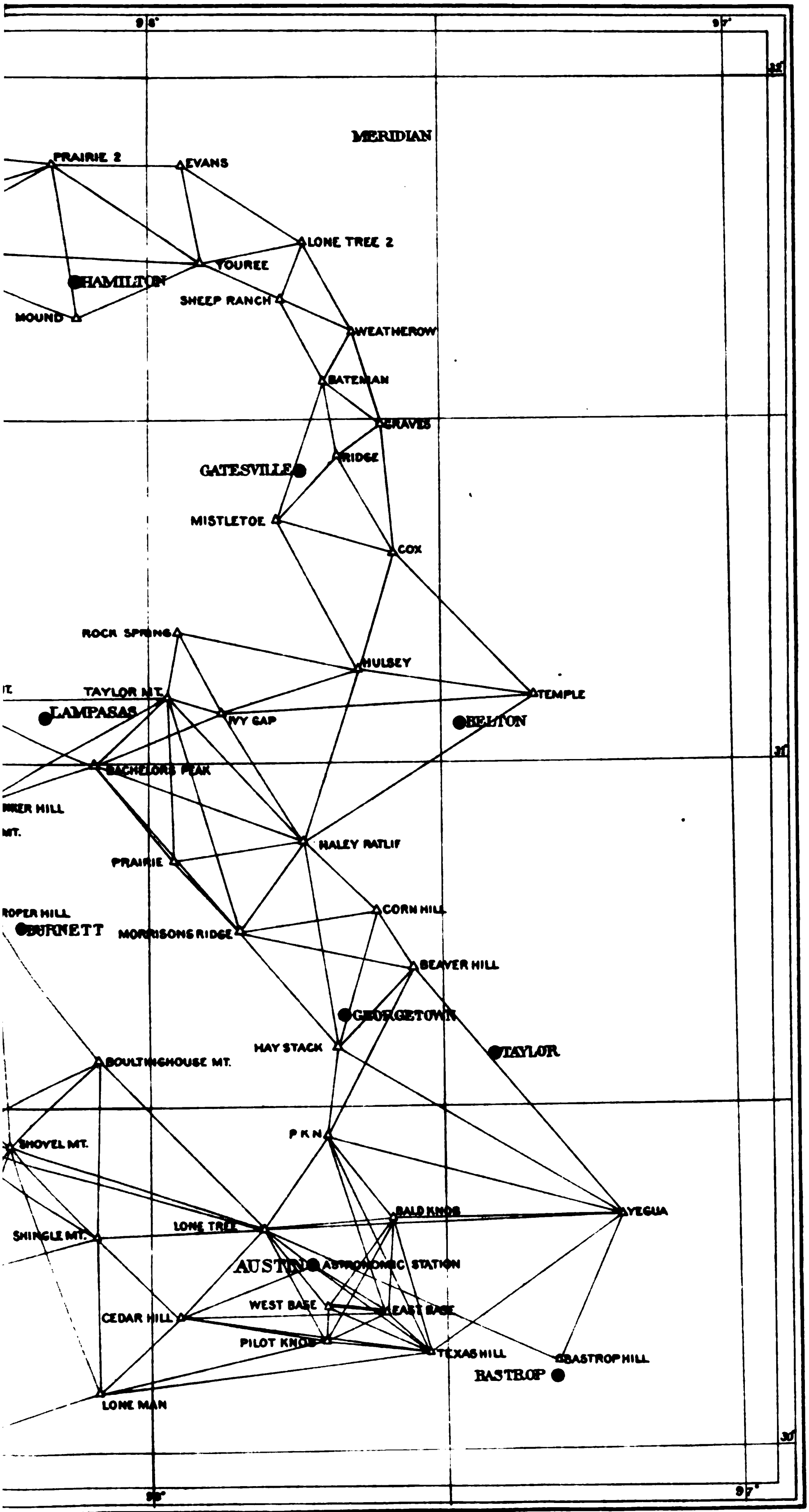
Upon the completion of his office work, January 1, 1887, Mr. W. H. Leffingwell, of this subsection, resigned.

During the winter months the topographers and their assistants have been engaged in reducing the triangulation and platting their maps, and, at the close of the fiscal year or before re-entering the field, the work of the previous season had been entirely completed and the maps prepared for the engraver.

SECTION OF TOPOGRAPHIC DRAWING.

During the year eight draftsmen on the average have been in the employment of the office, under the direction of Mr. Harry King, chief draftsman. Their work has been of the most miscellaneous character. The principal items may be enumerated as follows: the drawing of copies of the original sheets of the Massachusetts survey, for deposit with the State of Massachusetts; the compilation of a map of the United States; the compilation of a detailed map of the State of New York; and the preparation of large numbers of maps, drawings, etc., for illustrative purposes.


COLEMAN
MESQUITE
DOUBLE TREE
SANTA ANA
BROWNWOOD
LIME KILN
COWHOUSE
CABANISS
SAN SABA PEAK
ONION GAP
COW GAP
SAN SABA
ANTELOPE HILL
BRADY
WATERS
D.
BRADY
3 NOTCH
B.
MASON MT.
C.
MASON
LLANO
RILEY MT.
HOUSE MT.
BLUE MT.
BELL MT.
ROUND MT.
DIAGRAM
showing the progress of the
TRIANGULATION IN TEXAS
to the close of 1886
Scale
FREDERICKSBURGH
E
BLANCO
KERRVILLE
TWIN SISTERS
32°
31°
30°
99°


98°
97°
31°
MERIDIAN
PRAIRIE 2
EVANS
LONE TREE 2
YOUREE
HAMILTON
SHEEP RANCH
MOUND
WEATHEROW
BATEMAN
GRAVES
RIDGE
GATESVILLE
MISTLETOE
COX
ROCK SPRING
HULSEY
TEMPLE
TAYLOR MT.
LAMPASAS
IVY GAP
BELTON
BACHELORS PEAK
HALEY RATLIF
PRAIRIE
CORN HILL
BURNETT
MORRISONS RIDGE
BEAVER HILL
GEORGETOWN
HAY STACK
TAYLOR
BOULTINGHOUSE MT.
P K N
SHOVEL MT.
BALD KNOB
YEGUA
SHINGLE MT.
LONE TREE
AUSTIN
ASTRONOMIC STATION
WEST BASE
EAST BASE
CEDAR HILL
PILOT KNOB
TEXAS HILL
BASTROP HILL
BASTROP
LONE MAN
30°
98°
97°

SECTION FOR THE REPAIR AND MANUFACTURE OF INSTRUMENTS.

The mechanician, Mr. Edward Kübel, with two assistants, has been engaged during almost the entire year in repairing and modifying the large number of instruments in use by the Survey. In addition to this, he has manufactured theodolites for traversing and seismoscopes.

ENGRAVING.

In my last report it was stated that contracts had been made by the Public Printer with Messrs. Bien & Co. for the engraving upon copper of 120 sheets of the general topographic atlas, and that under these contracts 57 had been engraved. At the present date all the contracts have been completed, the plates transmitted to the keeping of this office, and a small edition (250 proof copies) of each sheet has been printed.

The following is a list of these sheets, which cover an area of approximately 250,000 square miles, or about one-fourteenth of the entire area of the country:

List of atlas sheets engraved July 1, 1887.

State or Territory.	Name of sheet.	Designation of sheet.		Area covered.	Scale.	Contour interval.
		Lat. ° ′	*Long.* ° ′			*Ft.*
Massachusetts	Greylock	42 30	73 00	Sixteenth degree	1:62,500	40
	Worcester	42 15	71 45	....do	....do	20
	Northampton	42 15	72 30	....do	....do	20
West Virginia	St. George	39 00	79 30	Quarter degree	1:125,000	100
	Raleigh	37 30	81 00	....do	....do	100
	Oceana	37 30	81 30	....do	....do	100
Maryland, Virginia, West Virginia.	Romney	39 00	78 30	....do	....do	100
Maryland, West Virginia.	Piedmont	39 00	79 00	....do	....do	100
West Virginia, Virginia.	Winchester	39 00	78 00	....do	....do	100
	Pocahontas	37 00	81 00	....do	....do	100
	Tazewell	37 00	81 30	....do	....do	100
West Virginia, Virginia, Kentucky.	Warfield	37 30	82 00	....do	....do	100
	Grundy	37 00	82 00	....do	....do	100
Kentucky	Prestonburgh	37 30	82 30	....do	....do	100
Virginia, Kentucky	Whitesburgh	37 00	82 30	....do	....do	100
Kentucky, Virginia, Tennessee.	Jonesville	36 30	83 00	....do	....do	100
	Estillville	36 30	82 30	....do	....do	100
Virginia, Tennessee	Bristol	36 30	82 00	....do	....do	100
Virginia, Tennessee, North Carolina.	Abingdon	36 30	81 30	....do	....do	100

List of atlas sheets engraved July 1, 1887—Continued.

State or Territory.	Name of sheet.	Designation of sheet.		Area covered.	Scale.	Contour interval.
		Lat. ° ′	Long. ° ′			Ft.
North Carolina	Cowee	35 00	83 00	Quarter degree	1:125,000	100
North Carolina and Tennessee.	Roan Mountain	36 00	82 00	...do	...do	100
	Greeneville	36 00	82 30	...do	...do	100
	Asheville	35 30	82 30	...do	...do	100
	Mount Guyot	35 30	83 00	...do	...do	100
	Knoxville	35 30	83 30	...do	...do	100
	Nantahalah	35 00	83 30	...do	...do	100
	Murphy	35 00	84 00	...do	...do	100
Tennessee	Morristown	36 00	83 00	...do	...do	100
	Maynardville	36 00	83 30	...do	...do	100
	Loudon	35 30	84 00	...do	...do	100
	Kingston	35 30	84 30	...do	...do	100
	Cleveland	35 00	84 30	...do	...do	100
South Carolina, Georgia.	Walhalla	34 30	83 00	...do	...do	100
Georgia	Dahlonega	34 30	83 30	...do	...do	100
Georgia, Alabama	Ringgold	34 30	85 00	...do	...do	10
	Rome	34 00	85 00	...do	...do	100
	Stevenson	34 30	85 30	...do	...do	100
Alabama	Fort Payne	34 00	85 30	...do	...do	100
Missouri	Sedalia	38 30	93 00	...do	...do	50
	Warrensburgh	38 30	93 30	...do	...do	09
	Harrisonville	38 30	94 00	...do	...do	50
	Warsaw	38 00	93 00	...do	...do	50
	Clinton	38 00	93 30	...do	...do	50
	Butler	38 00	94 00	...do	...do	50
	Bolivar	37 30	93 00	...do	...do	50
	Stockton	37 30	93 30	...do	...do	50
	Nevada	37 30	94 00	...do	...do	50
	Springfield	37 00	93 00	...do	...do	50
	Greenfield	37 00	93 30	...do	...do	50
	Carthage	37 00	94 00	...do	...do	50
Missouri, Kansas	Olathe	38 30	94 30	...do	...do	50
	Mound City	38 00	94 30	...do	...do	50
	Fort Scott	37 30	94 30	...do	...do	50
	Joplin	37 00	94 30	...do	...do	50
Kansas	Iola	37 30	95 00	...do	...do	50
	Fredonia	37 30	95 30	...do	...do	50
	Independence	37 00	95 30	...do	...do	50
	Parsons	37 00	95 00	...do	...do	50
Texas	San Saba	31 00	98 30	...do	...do	50
	Lampasas	31 00	98 00	...do	...do	50
	Taylor	30 30	97 00	...do	...do	50
	Georgetown	30 30	97 30	...do	...do	50
	Burnet	30 30	98 00	...do	...do	50
	Llano	30 30	98 30	...do	...do	50
	Mason	30 30	99 00	...do	...do	50
	Bastrop	30 00	97 00	...do	...do	50
	Austin	30 00	97 30	...do	...do	50
	Blanco	30 00	98 00	...do	...do	50
	Fredericksburg	30 00	98 30	...do	...do	50
	Kerrville	30 00	99 00	...do	...do	50

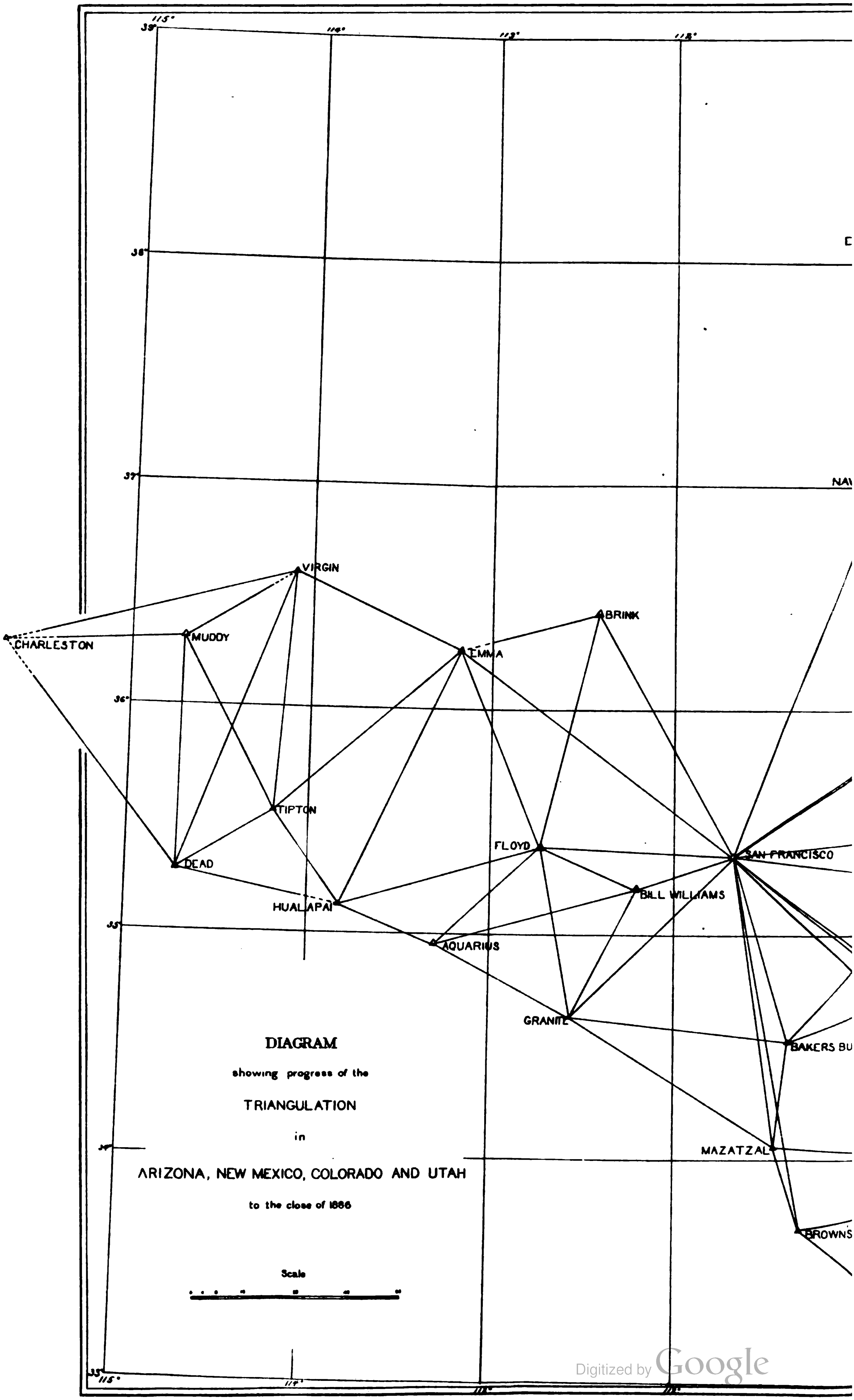
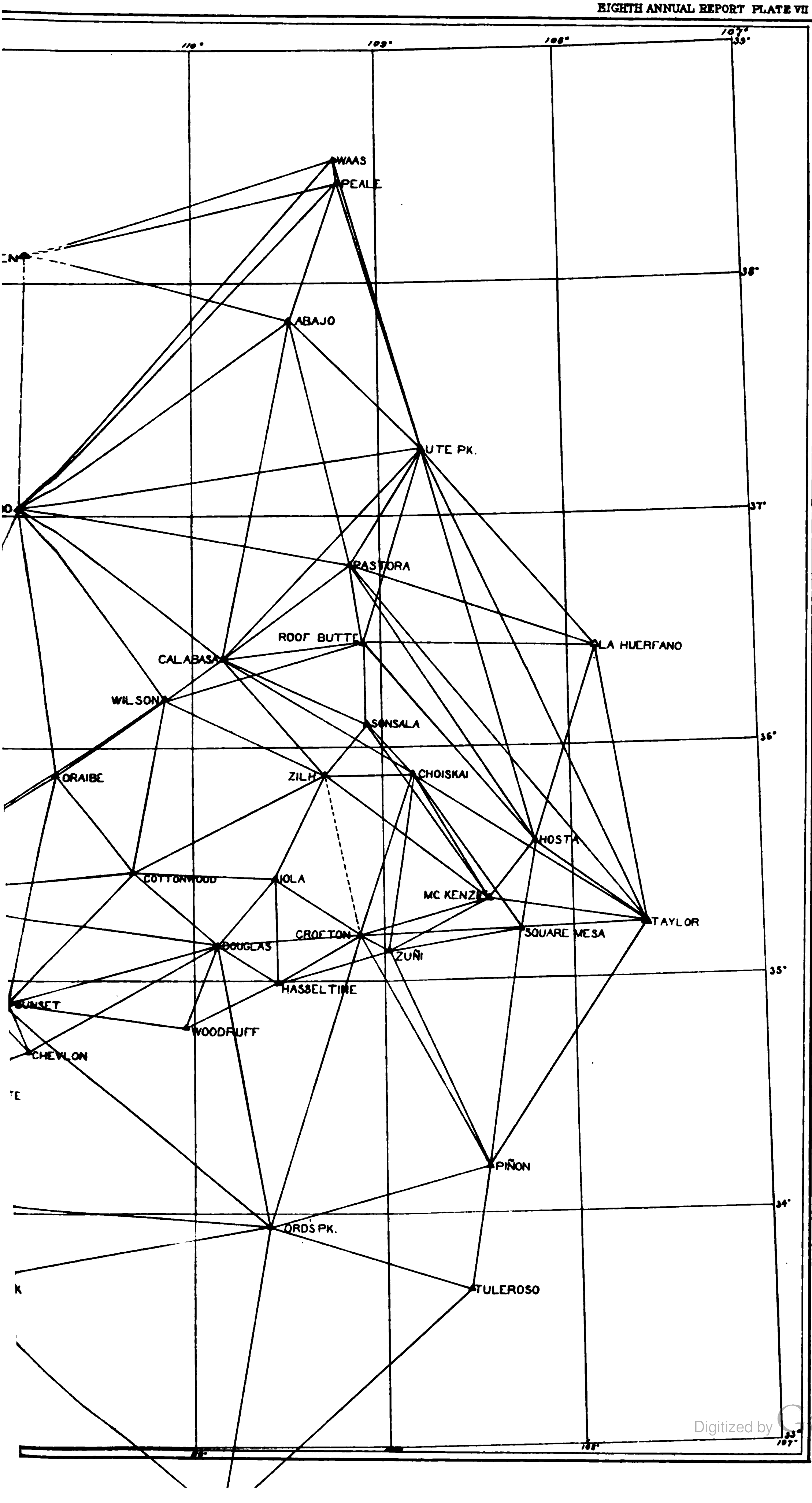


DIAGRAM
showing progress of the
TRIANGULATION
in
ARIZONA, NEW MEXICO, COLORADO AND UTAH
to the close of 1886
Scale
VIRGIN
CHARLESTON
MUDDY
BRINK
EMMA
TIPTON
DEAD
HUALAPAI
FLOYD
SAN FRANCISCO
BILL WILLIAMS
AQUARIUS
GRANITE
BAKERS BU
MAZATZAL
BROWNS
115°
114°
113°
112°
39°
38°
37°
36°
35°
34°
33°


110°
109°
108°
107°
39°
38°
37°
36°
35°
34°
33°
WAAS
PEALE
ABAJO
UTE PK.
PASTORA
ROOF BUTTE
LA HUERFANO
CALABASA
WILSON
SONSALA
ORAIBE
ZILH
CHOISKAI
HOSTA
COTTONWOOD
NOLA
MC KENZIE
TAYLOR
CROFTON
SQUARE MESA
DOUGLAS
ZUÑI
HASSELTINE
SUNSET
WOODRUFF
CHEVLON
PIÑON
ORDS PK.
TULEROSO

List of atlas sheets engraved July 1, 1887—Continued.

State or Territory.	Name of sheet.	Designation of sheet. Lat. ° ′	Long. ° ′	Area covered.	Scale	Contour interval. Ft.
Yellowstone National Park.	Gallatin	44 30	110 30	Quarter degree	1:125,000	100
	Cañon	44 30	110 00	....do	....do	100
	Shoshone	44 00	110 30	....do	....do	100
	Lake	44 00	110 00	....do	....do	100
Utah	Tooele Valley	40 00	112 00	Square degree	1:250,000	250
	Salt Lake	40 00	111 00	....do	....do	250
	Uinta	40 00	110 00	....do	....do	250
	Ashley	40 00	109 00	....do	....do	250
	Sevier Desert	39 00	112 00	....do	....do	250
	Manti	39 00	111 00	....do	....do	250
	Price River	39 00	110 00	....do	....do	250
	East Tavaputs	39 00	109 00	....do	....do	250
	Beaver	38 00	112 00	....do	....do	250
	Fish Lake	38 00	111 00	....do	....do	250
	San Rafael	38 00	110 00	....do	....do	250
	La Sal	38 00	109 00	....do	....do	250
	St. George	37 00	113 00	....do	....do	250
	Kanab	37 00	112 00	....do	....do	250
	Escalante	37 00	111 00	....do	....do	250
	Henry Mountain	37 00	110 00	....do	....do	250
	Abajo	37 00	109 00	....do	....do	250
New Mexico	Mt. Taylor	35 00	107 00	....do	....do	200
	Wingate	35 00	108 00	....do	....do	200
Utah, Nevada	Pioche	37 00	114 00	....do	....do	200
Arizona, Nevada	St. Thomas	36 00	114 00	....do	....do	250
Arizona, Nevada, California.	Camp Mojave	35 00	114 00	....do	....do	250
Arizona	Mt. Trumbull	36 00	113 00	....do	....do	250
	Kaibab	36 00	112 00	....do	....do	250
	Echo Cliffs	36 00	111 00	....do	....do	250
	Marsh Pass	36 00	110 00	....do	....do	200
	Cañon de Chelly	36 00	109 00	....do	....do	200
	Diamond Creek	35 00	113 00	....do	....do	250
	Chino	35 00	112 00	....do	....do	250
	San Francisco Mount'n	35 00	111 00	....do	....do	250
	Tusayan	35 00	110 00	....do	....do	200
	Fort Defiance	35 00	109 00	....do	....do	200
	Prescott	34 00	112 00	....do	....do	200
	Verde	34 00	111 00	....do	....do	200
Nevada	Paradise	41 00	117 00	....do	....do	200
	Disaster	41 00	118 00	....do	....do	200
	Granite Range	40 00	119 00	....do	....do	200
California	Alturas	41 00	120 00	....do	....do	200
	Modoc Lava Bed	41 00	121 00	....do	....do	200
	Shasta	41 00	122 00	....do	....do	200
	Red Bluff	40 00	122 00	....do	....do	200
	Lassen Peak	40 00	121 00	....do	....do	200
	Honey Lake	40 00	120 00	....do	....do	200
Montana	Great Falls	47 00	111 00	....do	....do	200
	Fort Logan	46 00	111 00	....do	....do	200
	Little Belt Mountain	46 00	110 00	....do	....do	200

At present there are in this office, completed and ready for the engraver, 123 sheets, which it is expected will be engraved during the coming fiscal year. These sheets cover 75,000 square miles and are distributed as follows:

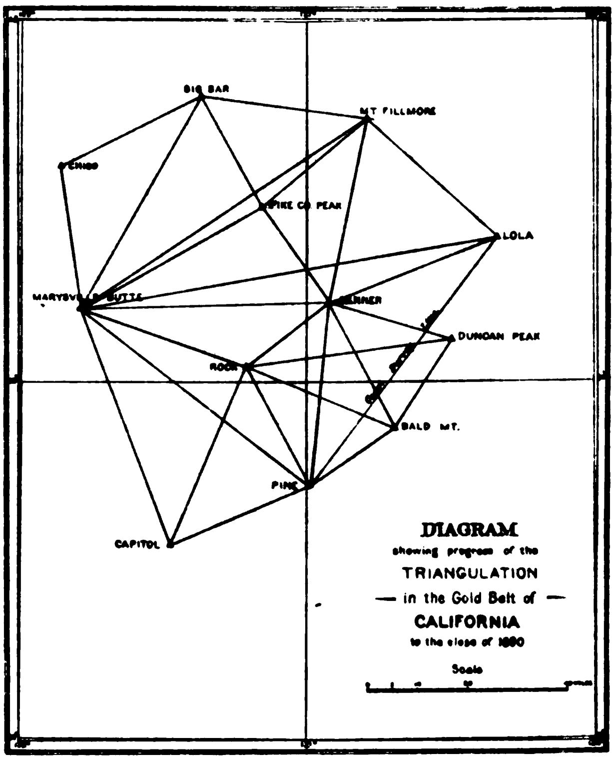
New Jersey	34
Massachusetts	30
District of Columbia	2
Appalachian region	22
Missouri	4
Kansas	22
Texas	4
Arizona	2
California	2
Montana	1
Total	123

DISCUSSION OF METHODS OF SURVEY.

The survey of the United States has now been in progress for five years and areas equivalent to one-fourteenth that of the country have been surveyed. These areas are widely distributed over the United States and involve nearly all the various natural and cultural conditions affecting methods of survey. The experience thus far obtained has resulted in the adoption of certain methods of work which appear to be those best suited for its economical prosecution.

The work of the topographer consists of two parts, clearly distinguished the one from the other in character. These are, first, the geometric control, which furnishes the skeleton of the map, and, second, the sketching, which furnishes the map itself. A map, therefore, from the constructive point of view, is a sketch corrected by geometric locations. The greater the number of the latter per unit of map surface (other things being equal) the more nearly correct is the map; but, however numerous they may be, the map itself is none the less a sketch. The topographer's work, therefore, is made up of two distinct branches, mathematical and artistic. The former is comparatively easy to master; the latter is rather a gift than an acquirement.

In devising plans and methods, the aim of the work has been recognized to be the production of a map upon certain scales, ranging in different parts of the country from 1:250,000 up to 1:62,500. No ulterior object has been in view, and, consequently, the character of the work has been throughout subordinate to this end, namely, that of making a map. The degree of refinement of the geometric control is such as, with a proper factor of safety, is necessary to avoid errors appreciable upon the adopted scale. The amount of control, i. e., the number of instrumentally located points per unit of map surface, is such as to reduce the errors of sketching to a minimum, and the


BIG BAR
MT FILLMORE
CHICO
PIKE CO PEAK
LOLA
MARYSVILLE BUTTE
DUNCAN PEAK
ROCK
BALD MT.
PINE
CAPITOL
DIAGRAM
showing progress of the
TRIANGULATION
— in the Gold Belt of —
CALIFORNIA
Scale

degree of detail in the sketching is proportional to the scale adopted for publication. Recognizing the fact that the definition of the scale sets the standard of the work as to both accuracy and detail, the aim is to attain that standard by the simplest and most economical methods; to avoid, on the one hand, making reconnaissance or sketch maps, which may be defined as those in which the sketching is not adequately controlled by geometric location, and, on the other hand, to avoid an excess of accuracy and fullness of geometric control beyond that which can be expressed in the map, as the time and money devoted to its attainment are not well spent.

The geometric control is effected by one or the other of two methods, either by angular measurement alone or by the measurement of direction and distance, the former being generally known as that of *intersection*, the latter as the *traverse* or meander method. The former is generally the preferable one, being the more accurate and rapid and in its prosecution affording the topographer better opportunities for the sketching which proceeds with it. Over parts of the country, however, especially in the flat, timbered regions, it cannot be economically employed, and almost everywhere, for the purpose of reaching the details of roads, streams, and other obscure features, the latter method is found to be a useful adjunct to it.

NORTHEASTERN SECTION.

In Massachusetts primary locations are furnished by the geodetic work of the Coast and Geodetic Survey, supplemented by the points established by the Borden (State) Survey, whose positions have been adjusted to suit the better determined points of the Coast and Geodetic Survey. Consequently, upon the inception of work in that State, there remained to be executed but little triangulation, as in nearly all cases a sufficient number of points were found for the inception of plane table work and for the correction of traverse lines. Both of the general methods above enumerated are pursued in this State. In the southeastern portion, where there is little relief and where the larger proportion of the country is covered with woods, the traverse method is followed to the practical exclusion of the other. Directions are measured by compass, distances by telemeter, and elevations by the vertical circle. The topographer, while thus mapping the plan and profile, makes locations off his line of route, using the latter as a series of base lines, and sketches the neighboring relief. In the northeastern part of the State, where the country is hilly, partially timbered, and densely settled, the work is done by the method of intersection, supplemented in great degree by traverses, which are run, as in the southeastern part of the State, by compass and telemeter. A considerable proportion of the locations and an equally large part of the topographic details are

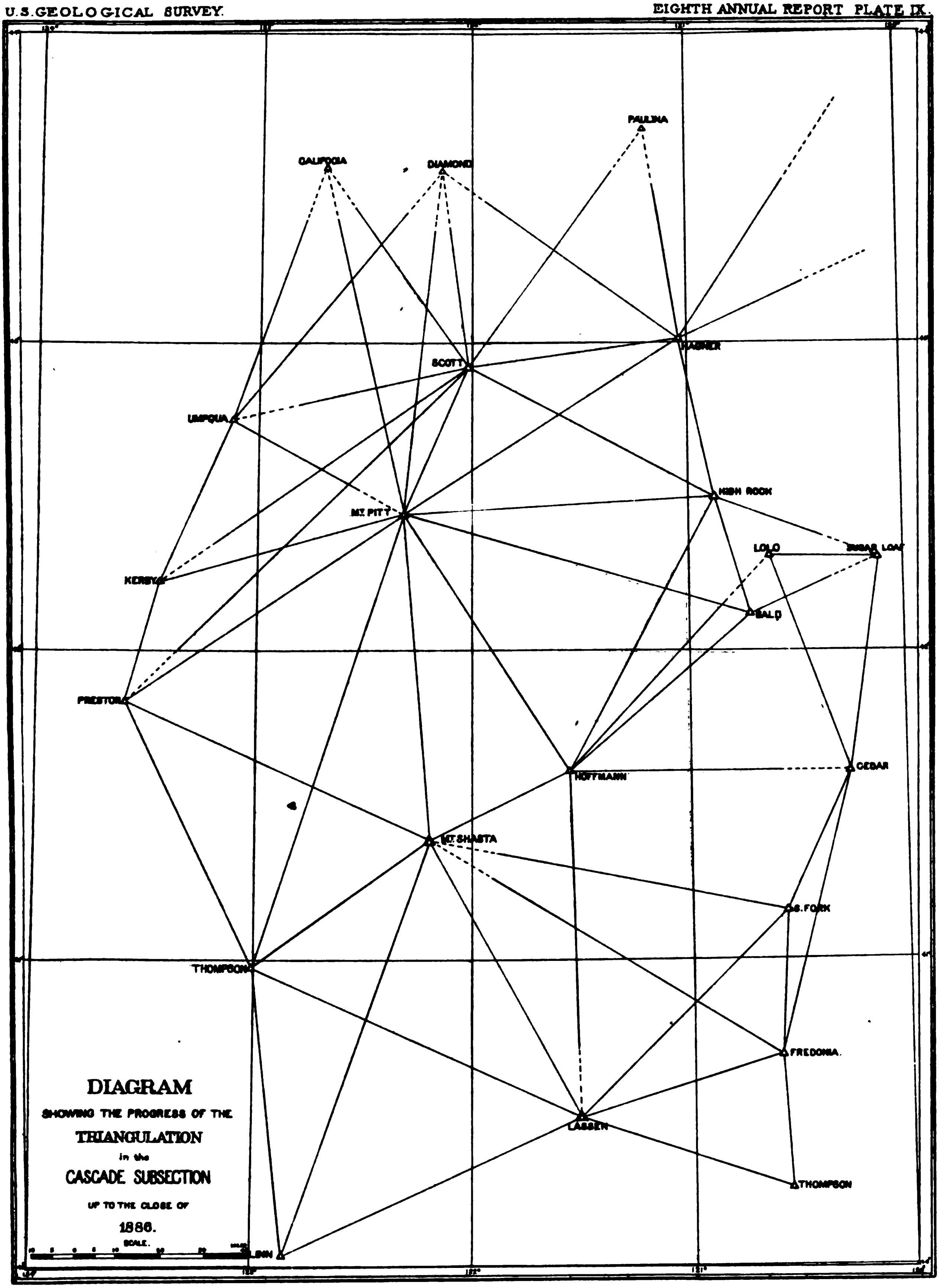
obtained by means of these traverse lines. The more general features of the country, particularly the hill work, are located and sketched from the plane table stations. In the western portion of the State, where there is considerable relief, consisting of large bold features, and where there is comparatively limited culture, the work is done entirely by intersection, the plane table being used exclusively for that purpose. Heights are determined by vertical angles with the alidade and by the aneroid barometer in a supplementary manner in the measurement of minor details of elevations. The experience of this season shows that each plane tabler, with one assistant, surveyed on an average 2.2 square miles, and each traverser, with a rodman, 2.3 square miles, per working day, the scale of publication being 1:62,500, or about one mile to an inch.

The methods used in New Jersey are those which were devised by the State survey while the work was being done by that organization. They have proved to be remarkably economical and the results excellent, especially in level or slightly undulating country. By these methods the horizontal and the vertical elements of the map are obtained by two distinct operations. An area is first traversed, the instruments used being a compass and a hand odometer, and the routes followed are mainly roads and principal streams. This survey, which furnishes a plan of the area, is platted and adjusted to the triangulation, and is in fact a map, wanting only in the vertical element. This map is then taken into the field by the leveler, who runs over the roads with a spirit level, determines their profile, establishing the heights of neighboring points, and sketches in the contours of the adjacent country, filling in the relief in the areas between the lines of survey as he goes.

In the survey of the sheets adjacent to the District of Columbia, the methods of work pursued in southeastern Massachusetts are followed closely.

APPALACHIAN SECTION.

The triangulation for the control of the maps in the Appalachian region rests throughout upon bases furnished by the work of the U. S. Coast and Geodetic Survey. Prior to the inception of work in this region by the U. S. Geological Survey, the former organization had carried a belt of triangulation from the Kent Island base, in Chesapeake bay, westward to the Blue Ridge, and thence southwestward, by a series of quadrilaterals and pentagons, as far as Atlanta, Ga., the westernmost points being upon the Blue Ridge or just below it and the easternmost points upon the outlying summits or ridges upon the Atlantic plain. At Atlanta a second base was measured, the Peach Tree base, and thence the triangulation was continued westward to the neighborhood of Huntsville, Ala. From a point in this triangulation, in central Virginia, a belt was carried westward across


PAULINA
DIAMOND
SCOTT
UMPQUA
MT PITT
KERBY
PRESTON
HIGH ROCK
LOLO
SUGAR LOAF
BALD
HOFFMANN
CEDAR
MT SHASTA
S. FORK
THOMPSON
FREDONIA
LASSEN
THOMPSON
DIAGRAM
SHOWING THE PROGRESS OF THE
TRIANGULATION
in the
CASCADE SUBSECTION
UP TO THE CLOSE OF
1886.
SCALE.

the Shenandoah valley and the Alleghany plateau to the Ohio river, forming a portion of the transcontinental belt.

The triangulation of the Geological Survey lies west and north of the Appalachian belt of the Coast and Geodetic Survey, connecting with it along its whole extent and using severally all of the westernmost lines of that belt as its base lines.

The instruments used are 6 and 7 inch theodolites, reading by vernier to 10 seconds. Throughout the work, the signals used are artificial, consisting of single trees isolated by cutting the timber from around them, of tripods consisting of three trees with heads lashed together and a tuft of brush left upon them, ordinary tripod signals, and other forms. In many cases heliotropes are used, and found almost indispensable upon long lines, on account of the haziness of the atmosphere. The length of lines varies greatly, but is in few cases less than 8 or more than 30 miles. Angles are read both by the method of directions and by repetition, and the ordinary methods for the elimination of eccentricity and of errors of division are employed.

The office reductions consist, first, in a local adjustment by least squares, introducing the ordinary conditions; then the angles are reduced to center in case they were observed off center; then follows a figure adjustment, the work being divided for this purpose into simple figures, such as quadrilaterals, pentagons, hexagons, etc., the adjustment being effected by the method of least squares.

With these corrected angles, the computation of latitude, longitude, and azimuth is carried forward from one base line to another and a check is thus obtained upon the distance, latitude, longitude, and azimuth, and the further corrections derived therefrom are distributed backward. In all cases the errors thus detected were trifling in amount when the purpose of the triangulation is considered, as is seen by the following statement regarding these circuits (see Plate IV):

Starting at Blood-Rabun, passing around by stations Thomas Bald, Cowee, Cheowah, Thunderhead, Christie Peak, Haw Knob, Tusquittah, Pack, Chilhowee, Cowpen, and closing on the line Grassy-Blood, the errors are as follows:

Distance, 7.7 feet.	Latitude, 00″.08.
Azimuth, 0″.0.	Longitude, 0″.00.

Starting at Gulf-Johns, passing by stations High Point, Rocky Face, Grindstone, and closing on Chilhowee 4-Cowpen, the errors are as follows:

Distance, +6 inches.	Latitude, −0″.20.
Azimuth, −29″.8.	Longitude, −0″.18.

At Cowpen the error in latitude is −0″.22; in longitude, −0″.04.

Starting at Grindstone–Chilhowee 4, passing by stations Texas, Roy, Hinch, Melton, Chilhowee 2, Chilhowee 1, and closing on Thunderhead–Christie Peak, the errors are as follows:

Distance, —1. 79 feet.	Latitude, —0". 22.
Azimuth, —0". 6.	Longitude, —0". 01.

Starting at Benn–Poore, passing by the stations Grandfather, Snake, Negro, Balsam, Lookout, Ripshin, Big Bend, Draper, Rich, and closing on the line Moore–Buffalo, the errors are as follows:

Distance, +8 inches.	Latitude, +0". 10.
Azimuth, —20". 2.	Longitude, —0". 40.

Starting at the line Big Bald–Roan, passing by the stations Chimney, Holston, High Knob, Clinch, Big Butt, Red Rock, Morris, and closing on the line Ripshin–Rogers, the errors are as follows:

Distance, —20. 3 feet.	Latitude, —0". 63.
Azimuth, —47". 5.	Longitude, +0". 64.

Starting at the line Melton–Chilhowee 1, passing by the stations House, English, Short, Chucky, and closing on the line Chimney–Big Bald, the errors are as follows:

Distance, —8. 8 feet.	Latitude, —0". 19.
Azimuth, —47". 2.	Longitude, +0". 50.

Topographic work in this section combines the two methods of location, but their relative importance constantly varies with the character of the country in which the party is at work. Ordinarily, the head of the party carries forward, with an instrument reading to minutes, a secondary triangulation, making, in connection therewith, all locations possible by angular measurement and sketching such portion of the country as can be safely reached from his stations. Connected with the party there are usually from two to four men engaged constantly in traversing. The traverses are run with compass and odometer, usually by means of a cart, although the hand odometer is used to a limited extent. Connections are made from the traverse lines to located points, thus checking the line at short intervals. All topography adjacent to the line is sketched and is located by cutting in points with the compass. Elevations are measured by cistern or aneroid barometer and by the vertical circle of the theodolite.

CENTRAL SECTION (PLATE V).

The work of this section is somewhat peculiar, owing to the fact that the area occupied by it has been subdivided by the General Land Office, thereby not only establishing, with a considerable degree of accuracy relatively to one another, points at intervals of half a mile, but also furnishing maps of the drainage of the region. These drain-

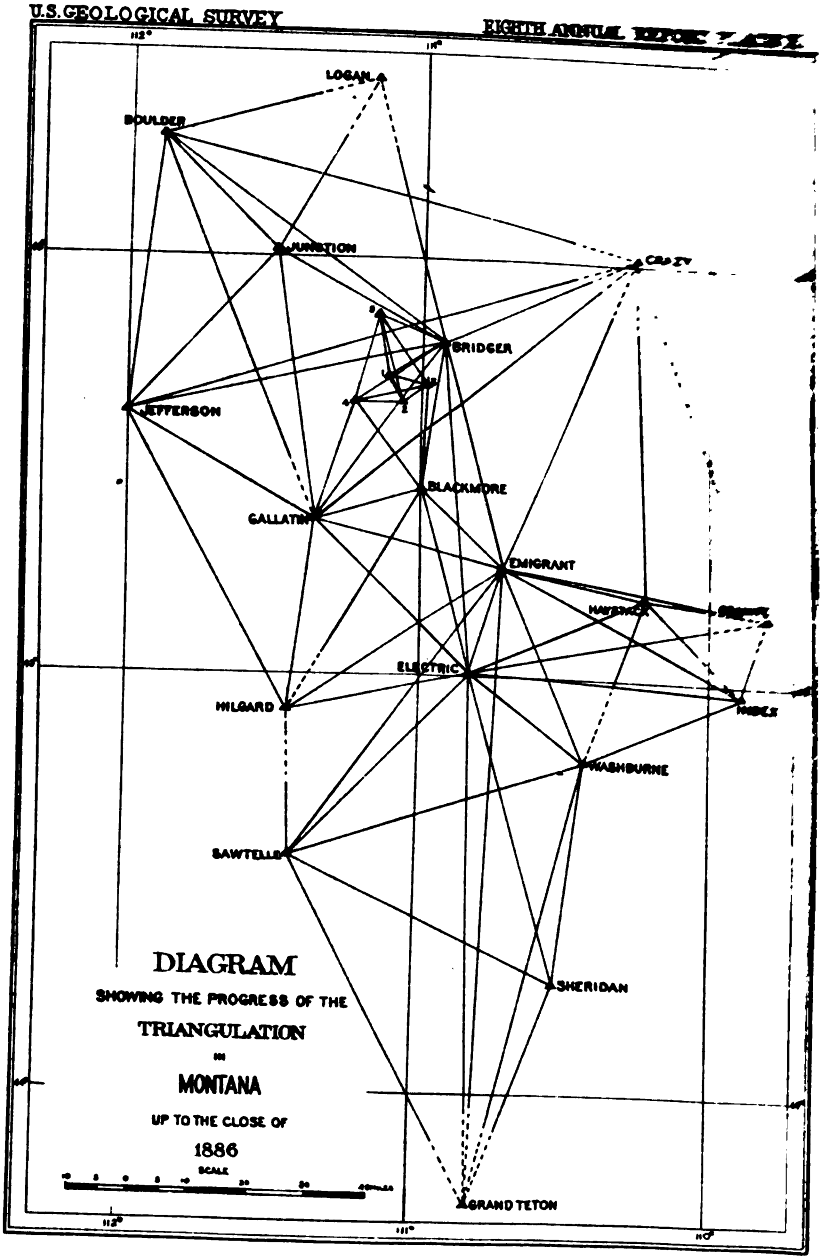


DIAGRAM
SHOWING THE PROGRESS OF THE
TRIANGULATION
IN
MONTANA
UP TO THE CLOSE OF
1886

age maps are more or less imperfect. The larger streams have been traversed by the land surveyors, but the smaller streams are located at intervals not usually less than a mile, the remaining portions being sketched. The work of this section consists, first, in the extension of a system of control over the land surveys, with a view to checking up and eliminating accumulated errors; secondly, in verifying and supplementing the drainage represented upon the plats; and, thirdly, in supplying the relief and culture elements.

The areas surveyed in Missouri are traversed by the transcontinental belt of triangulation of the U. S. Coast and Geodetic Survey, and for their control it has been necessary only to connect the stations of this triangulation with section corners in order to establish the relation between them. This triangulation had not, however, been extended into the Kansas area, and it was found necessary to execute the means of control in that area. This has been done by carrying an east and west belt of triangulation across the area to be surveyed, midway of each degree of latitude. Such belts have been carried through in approximate latitude 38° 30′ and 39° 30′, terminating at the westward near the meridian of 97°. Each station was connected with at least one section corner. The work was executed with an 11-inch Gambey theodolite, reading by vernier to ten seconds, and artificial signals were used throughout, consisting of tripods of sawed lumber, bearing flags. The work was adjusted by least squares, using simple figures, quadrilaterals or pentagons.

The topographic work in Kansas is of the simplest possible description, consisting of little besides sketching. Under State law, a road is constructed upon nearly every section line and very frequently upon quarter-section lines, while, in addition to those landmarks, the country is in many cases still more minutely subdivided, the division lines being indicated by fences and hedges, thus furnishing a means of location in great detail. Heights are obtained from the profiles of railroads and by the use of the cistern and aneroid barometers, and, as the surface of the country is extremely uniform in character, the matter of the determination of elevations is very simple.

In Missouri the work is not of so simple a character. In the prairie portions of the State the country is to a certain extent graphically subdivided by means of roads, fences, and hedges, furnishing large numbers of located points, and there the methods are quite similar to those pursued in Kansas. In the hilly, timbered portion of the State, however, which comprises most of the country south of the Missouri river, the roads do not follow the section lines and the location of section corners is not easily ascertained. The methods pursued in this region are mainly those of traversing, checking the traverses upon section lines and corners wherever these can be identified, and sketching the country from these traverses.

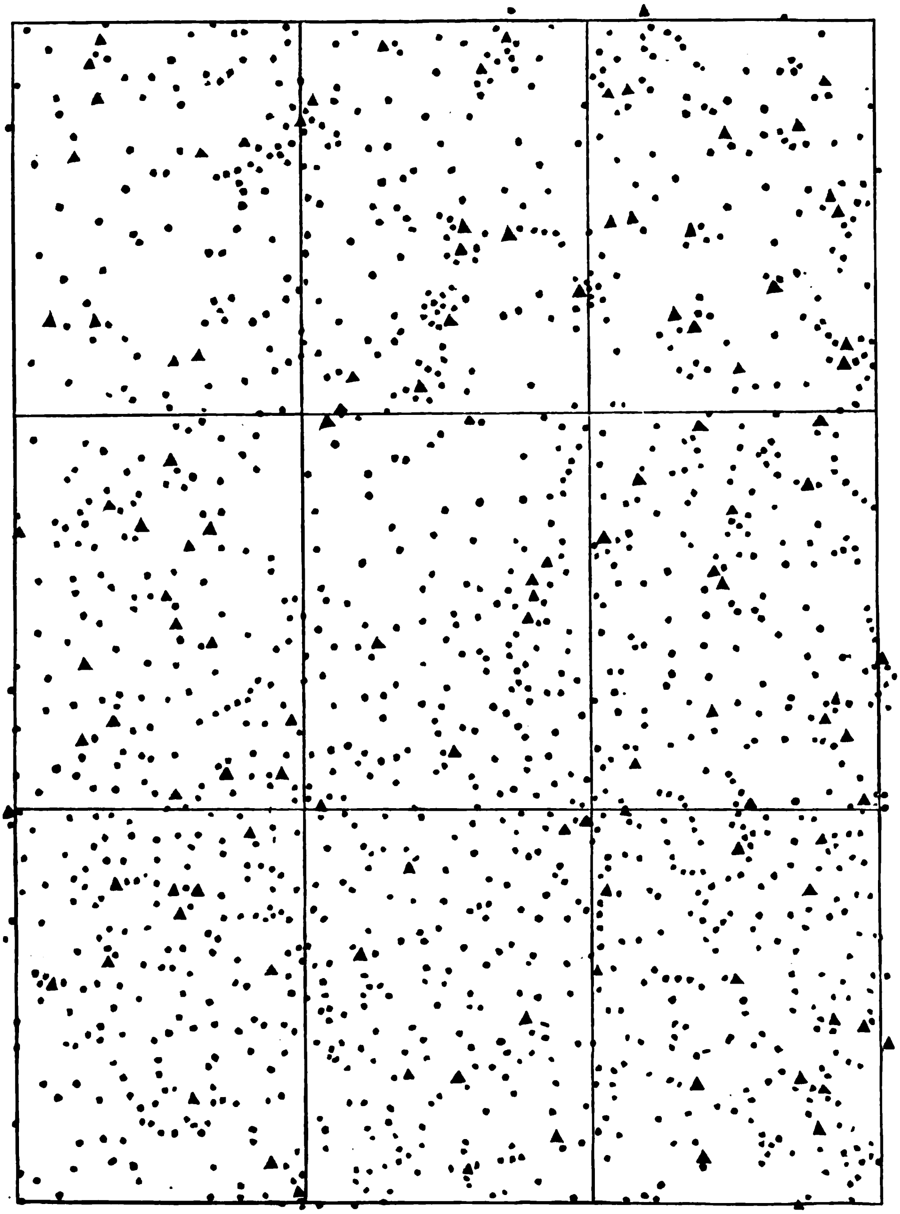
WESTERN SECTION (PLATES VI-X).

The triangulation in Texas proceeds from a base measured with four-meter secondary bars and expanded into a network of figures covering the area surveyed. The measurement of angles has been executed with a theodolite of 8-inch circle, reading by vernier to ten seconds. Artificial signals, consisting mainly of tripods of sawed lumber, have been used throughout the work. The work is adjusted, as elsewhere, by least squares. Topographic work in this area is carried on by the plane table, used as an intersection instrument, and by traverse with compass and odometer. The plane table is used for the location of numerous points and for sketching such areas as can be reached from the stations, while the greater part of the topography is obtained by means of the traverse lines. Elevations are determined, as in the Appalachian work, by cistern and aneroid barometers and by the vertical circle of the theodolite.

The triangulation in Arizona and the neighboring Territories rests upon a base measured near Fort Wingate, N. Mex., whence it has been extended over large areas in northern Arizona, southern Utah, and southern Nevada. The instrument used is a 10-inch theodolite, reading by vernier to five seconds. In the expansion artificial signals were used entirely, but in the subsequent triangulation, which proceeds among high mountains and by long lines, natural summits are as a rule sighted upon, a station being marked upon occupation, usually by a cairn of stones. The adjustment of the work has been made, as in other cases, by least squares, adjusting the figures severally. Topographic work is carried on by the method of intersection with the plane table. In the mountainousco untry little or no traversing is done, but in the level regions, which form a large portion of the area surveyed, roads and trails are traversed by compass and odometer, and a large proportion of the topography is obtained therefrom.

The triangulation for the control of the work of the gold belt subsection, which is upon the western flank of the Sierra Nevada, rests upon the Yolo base, in the Sacramento valley, measured by the U. S. Coast and Geodetic Survey. This work is carried on with a 7-inch theodolite, reading by vernier to ten seconds, and artificial signals are used throughout. Topographic work is done mainly by plane table, but it is supplemented, even in this rugged mountainous country, by a large amount of traversing, the same instruments being used for this purpose as in other parts of this subsection.

In the Cascade subsection triangulation rests upon the line Mt. Shasta–Lassen Peak, as determined by the geodetic work of the U. S. Coast and Geodetic Survey. From this line triangulation has been extended over northern California and southern Oregon. The instrument used is an 8-inch theodolite, reading by vernier to ten



STATIONS—▲ LOCATIONS by INTERSECTION—•

INSTRUMENTAL CONTROL OF TOPOGRAPHY IN MASSACHUSETTS · BECKET SHEET.

seconds. Artificial signals are rarely employed, as the sights are very long and the stations are the summits of lofty mountains. The topographic work is carried on by methods closely analogous to those pursued in Arizona and the gold belt, viz: by the plane table, supplemented in some degree by traverses. The proportion of work done, however, by means of the latter method is comparatively small.

In the Montana subsection the triangulation proceeds from a base measured near Bozeman, Mont., which has been expanded eastward, southward, and westward. High mountain summits are used as stations and few signals have been employed outside of the expansion, beyond cairns of rocks erected at the time of occupation. The topographic work is carried on almost entirely by the plane table, employing the method of intersections. Little traversing is done, as the necessity for it is almost entirely obviated by the character of the country, which consists of rugged mountains alternating with comparatively narrow valleys. Elevations are measured, as everywhere throughout this section, by the cistern and aneroid barometers, together with the vertical arc of the gradienter.

MEASURE OF THE GEOMETRIC CONTROL.

The sufficiency of the geometric control may be discussed from three different aspects: (1) Its accuracy; (2) its amount, i. e., the average number of points instrumentally located per unit of area; and (3) the distribution of these points.

Below are presented statistics and diagrams illustrating the character of the control of the work for the past year. As to the question of accuracy, it is possible to give statistics relating to the primary work only, the secondary locations not being computed, but simply platted, either with the protractor or the alidade. With regard to them it can only be stated that no errors which are sufficiently great to be appreciable upon the scale of publication are permitted. The quality of the primary work is summarized in the following table, showing the average errors of closure of triangles:

Fields of work.	Number of triangles.	Average error of closure.
		$''$
Appalachian region	170	16.00
Kansas	38	6.60
Texas	171	7.00
Arizona etc	69	9.30
Gold belt	23	20.39
Cascade mountain region	15	22.04

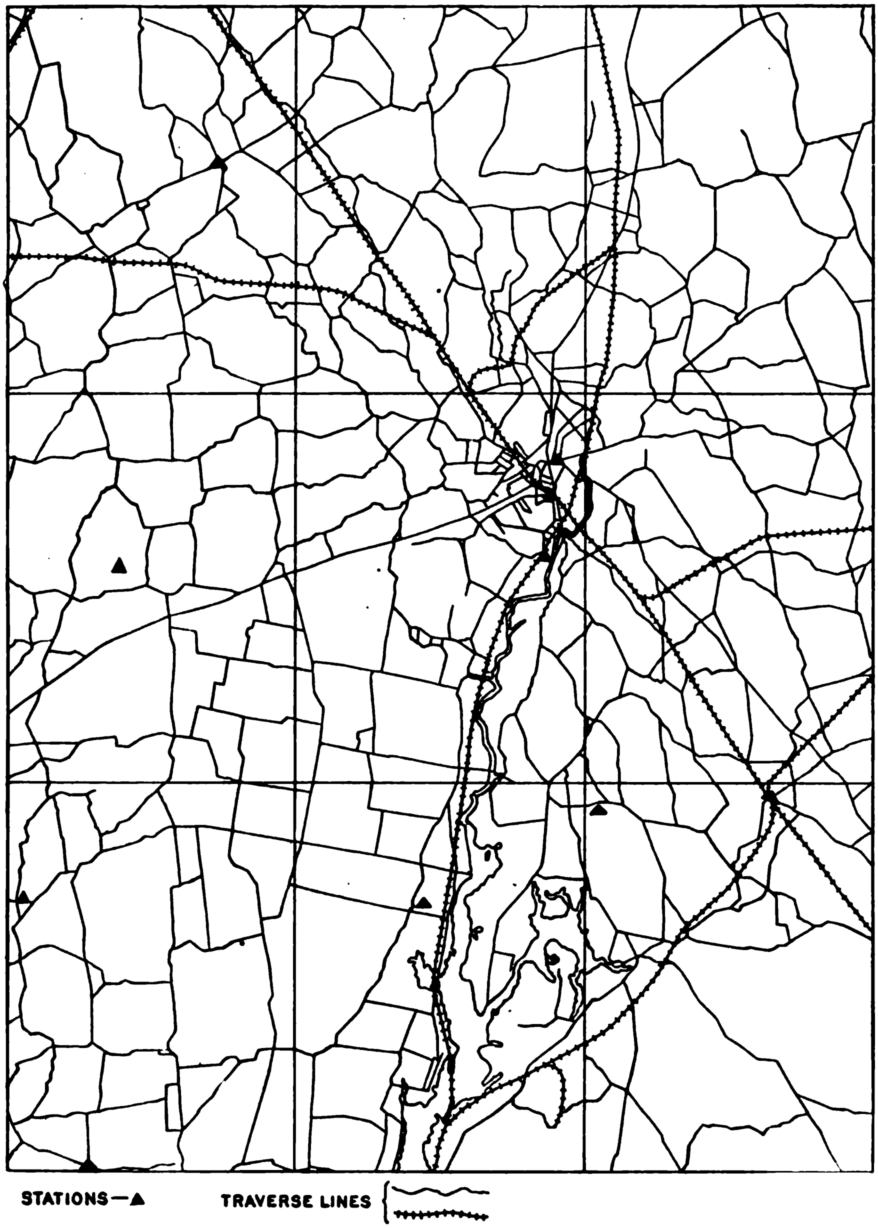
With reference to the number of locations per unit of map surface the following table is presented, showing (1) the region; (2) the area considered, which it will be noticed is in many cases less than the total

area surveyed, as reported heretofore; (3) the number of plane table or theodolite stations occupied; (4) the number of points located by intersection of lines of sight from occupied points; (5) the number of traverse stations; (6) the total number of points located, i. e., the sum of columns three, four, and five; and (7) the number of locations per square inch of map surface on the scale of publication. The unit of area adopted, it will be observed, is the square inch of published map. This has been chosen for the purpose of eliminating the question of scale from consideration, and thus making all maps, whatever their scale, directly comparable, so far as this element is concerned.

1.	2.	3.	4.	5.	6.	7.
Region.	Area considered.	Plane table stations.	Locations by intersection.	Traverse stations.	Total located points.	Locations per square inch of published map.
	Sq. miles.					
Massachusetts, plane table work	1,346	1,332	7,485	....	8,817	6.6
Massachusetts, traverse work	677	....	....	16,366	16,36[illegible]	24.2
Massachusetts, mixed work	676	212	916	6,867	7,995	11.8
New Jersey	1,264	....	....	26,107	6,107	20.7
Appalachian region	19,054	361	5,160	133,616	139,137	29.2
Texas	4,430	72	193	10,189	10,454	9.4
Arizona	7,620	92	466	1,143	1,701	3.6
Gold belt, California	1,861	142	1,657	6,358	8,157	17.5
Oregon	3,000	72	770	995	1,837	9.8
Montana	3,300	53	610	74	737	3.6

The figures shown in the above table require certain qualifications. For equal accuracy in the survey, different areas require a greater or lesser number of points per unit of area. A low rolling country requires fewer locations than a rugged mountainous one; a country of large bold features requires fewer than one of minute detail; an unsettled country, containing little culture, requires few as compared with a densely settled area.

Again, there is a great difference in the character of the locations. As a rule, traverse locations are by no means so valuable for the purpose of correcting the map as those by intersection. The latter are selected points, chosen for the express purpose of location as being key points, each of them being presumably the one best adapted for controlling the sketch in its immediate neighborhood; they may be mountain summits, shoulders of spurs, junctions of streams, crossings of roads, churches, etc. On the other hand, traverse stations, as a rule, are not selected points. They follow the roads. A large proportion of them are located simply for the purpose of carrying forward the line, and few of them are points which would be selected as key points for controlling area. It is, however, difficult to estimate the relative value of the two classes of locations, but it may be said



INSTRUMENTAL CONTROL OF TOPOGRAPHY IN MASSACHUSETTS; TAUNTON SHEET.

that, in the case of the Massachusetts work, the plane tabled area is fully as well controlled, with its 6.6 points per square inch, as the traverse work, with its 24.2 points.

The above table has reference only to the question of horizontal location. In regard to the measurement of heights and the vertical location of the work, it may be said that the number of measurements closely approximates that of the horizontal locations.

In this table the Missouri and Kansas areas have not been represented. This is because the work done in those States is of so different a character that it cannot be measured by the method above used. It is essentially sketching, connected with height measurement, and the measure of the thoroughness of the work may be expressed by stating that in Kansas a mile of traverse was run for every 2.6 square miles of published map and in Missouri for every 2.3 square miles. The great uniformity of the prairies of Kansas, as contrasted with the broken hill country of Missouri, easily explains the difference in the amount of work done per square mile.

As to the distribution of locations, it may be said that they are distributed as uniformly as the nature of the country permits and the map requires. The distribution is illustrated in the accompanying plates, taken at random from the work of the past year: Plate XI is from the plane table work in Massachusetts; Plate XII, from the traverse work in the same State; Plates XIII and XIV are from the Appalachian region, the former being in the Tennessee valley and the latter mainly comprised in the mountain region of eastern Tennessee and western North Carolina; Plate XV represents the control in the undulating country of central Texas. It will be remembered that these plates are designed to show simply the distribution and not the amount of the control.

TRAVERSE WORK.

Traverse work is carried on in all of the areas under survey, excepting western Massachusetts. In some cases, as in southeastern Massachusetts, where the country is low and rolling and largely covered with timber, and in southern New Jersey, where similar conditions prevail, all the work is done by traverse. In other cases traverse work is carried on in connection with plane table work and in a manner more or less subsidiary to it. In the Appalachian region and in Texas most of the topographic details are obtained by it. In the mountain region of the far West it is carried on to a less extent and the results are much more subordinate to the work of the plane table.

In the traverse work done in Massachusetts and in the region adjacent to the District of Columbia directions are read by compass, with a minute reading instrument, and distances by the telemeter, differences of elevation being read upon the same rod. During the

past season 3,651 linear miles were run by this method in Massachusetts. The average number of miles run per man per working day was 6.3. The average daily output of the different men employed upon this work ranges from 3.7 to 10.8 miles for the whole season, the latter average being reached by Mr. J. H. Jennings, of Mr. Natter's party. The average number of traverse stations made per day per man was 41 and the average number of stations per mile ranged from 4 to 9.8, the smallest number of stations per mile accompanying the most rapid rate of work.

The traverse work done in New Jersey, in the Appalachian region, and in the West was carried on by compass and odometer, and, with the exception of New Jersey, elevations were measured in connection with this work by the barometer. In New Jersey the number of miles run during the season was 2,793 and the average number of miles run per day per man was 9. Ninety stations were made per day, or at the rate of 10 per mile.

An example of traverse work of this character upon a larger scale is furnished by the Appalachian work. In this section thirty-two men were employed in traversing. They meandered during the season a distance of 11,817 miles and occupied 133,616 stations. The average distance traversed per day per man was 9.5 miles and the average number of stations per day was 108, while 11.3 stations were occupied to each mile. As in the case of the telemeter work in Massachusetts, the greatest average output of the different men, viz, 15.5 miles, accompanies the smallest number of stations per mile, viz, 3; while, on the other hand, the smallest number of miles per day (6.5) is accompanied by an average of 17.5 stations per mile, which is one of the greatest recorded.

The above figures in regard to the traverse work in the Appalachian region have reference to the work done with wagons. A comparison of this with the work done by hand odometers shows a slight advantage in point of rapidity in favor of the wagon, but not so decided a gain as might have been anticipated.

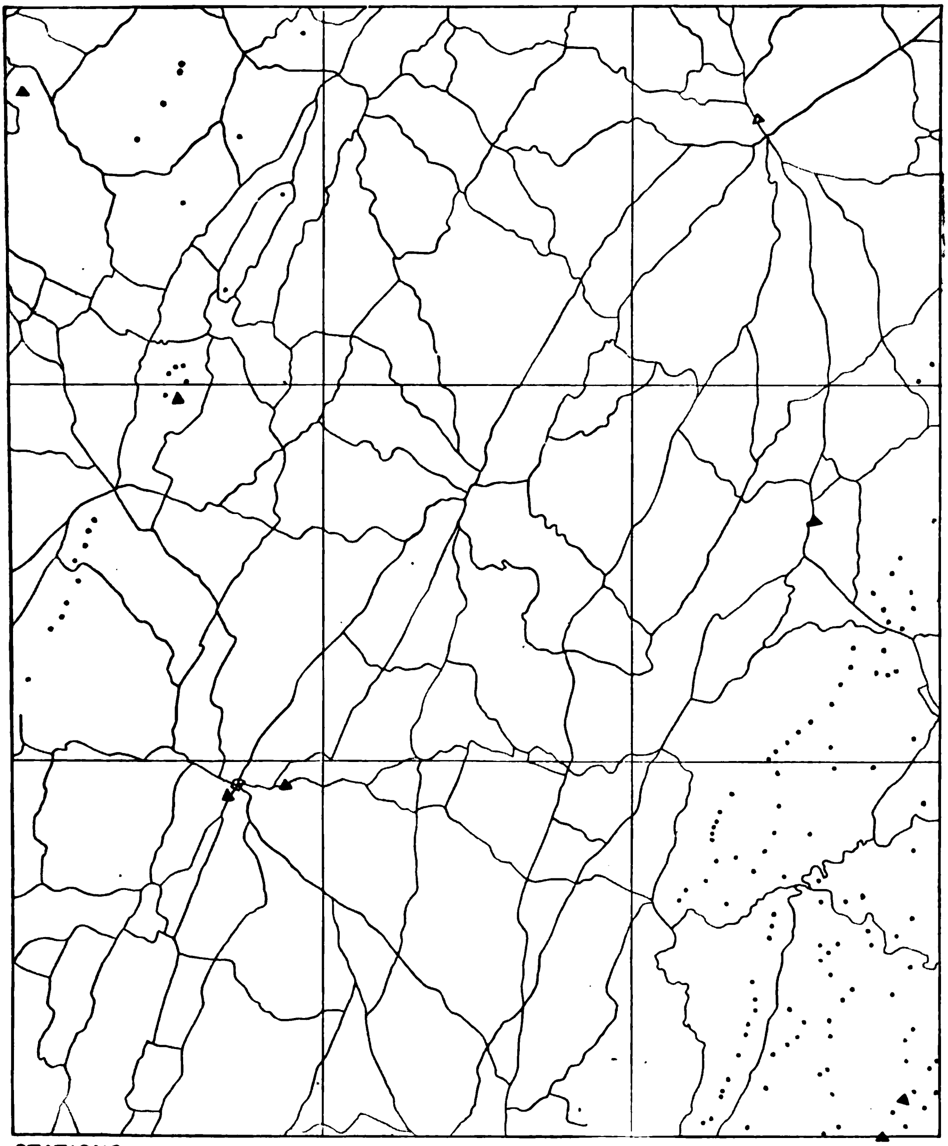
In discussing the traverse work, of course, account should be taken of the difference in the character of the roads, as to their relative directness, both in the horizontal and vertical planes, since upon this depends, in a very great measure, the rapidity of the work.

I have the honor to transmit herewith the report of Mr. R. S. Woodward.

Very respectfully,

HENRY GANNETT,
Geologist in Charge of Geography.

Hon. J. W. POWELL,
Director U. S. Geological Survey, Washington, D. C.



STATIONS — ▲ LOCATIONS by INTERSECTION — • TRAVERSE LINES

INSTRUMENTAL CONTROL OF TOPOGRAPHY IN TENNESSEE; CLEVELAND SHEET.

DEPARTMENT OF THE INTERIOR,
U. S. GEOLOGICAL SURVEY,
DIVISION OF GEOGRAPHY,
Washington, D. C., July 1, 1887.

SIR: I have the honor to submit, through Mr. Henry Gannett, the following report on office and field work for the fiscal year just closed:

GEOGRAPHICAL WORK.

Office computations etc.—During the last year, as heretofore, a large portion of the work falling under my charge was directly auxiliary to the work of the division of geography. Of the various computations which have been made or completed within the year for that division the following are the most important:

(1) A set of tables giving the co-ordinates for the polyconic projection of maps for each of the scales 1: 30,000, 1: 62,500, 1: 63,360, 1: 125,000, 1: 126,720, and 1: 250,000.

(2) A table giving the areas in square miles of quadrilaterals of the earth's surface bounded by meridians and parallels.

(3) A table for facilitating the computation of differences of height from angles of elevation or depression.

(4) A table giving differences in elevation from telemeter measures.

(5) A table similar to the last, but adapted to a special scale for plane table work.

(6) Two sets of tables for facilitating the determination of azimuth from observations of Polaris.

The tables under (3), (4), and (5), above, have already been printed for the use of the topographers in the field, and it is probable that the extensive use of the other tables would justify their publication also.

Another work which is directly contributory to the division of geography is the collection, classification, and arrangement for ready reference of geographical positions of points within the United States. Our list of such positions now embraces upwards of seven thousand entries. The chief sources from which these have been drawn are the Reports of the U. S. Coast and Geodetic Survey, the U. S. Lake Survey, the various United States geographical and geological surveys, the Mississippi River Commission, and the State surveys of Massachusetts and New York. About two hundred positions were added to the list during the year. Constant attention is paid to keeping the list up to date, so that all available geographical positions may be readily placed at the disposal of the geographers or draftsmen.

The definitive latitudes and the approximate longitudes of certain primary points determined astronomically by me in 1884 and 1885

in Missouri, Kansas, and New Mexico were published in the report of the geologist in charge of geography in the Annual Report of the Survey for 1886. During the year the complete results of that astronomical work were collected and discussed with such detail as seemed necessary to render them most useful. These results, which embrace the latitudes and longitudes of six primary points and thirty-eight points geodetically dependent thereon, together with their discussion, were transmitted for publication in the form of a bulletin.

Survey of Niagara Falls.—Early in August last I received instructions to make a survey of the Falls of Niagara, the object of which was to determine their rates of recession by comparing the present positions of the crests with their positions as determined by the New York State Geological Survey in 1842 and by the U. S. Lake Survey in 1875.

This work was completed August 25, 1887. It embraced the fixation by intersections of thirty points on the crest of the Horse Shoe fall and twenty-five points on the crest of the American fall. Additional limitations and checks on the positions of the crests were secured by numerous tangents, which were observed wherever possible. The heights of both falls were also measured.

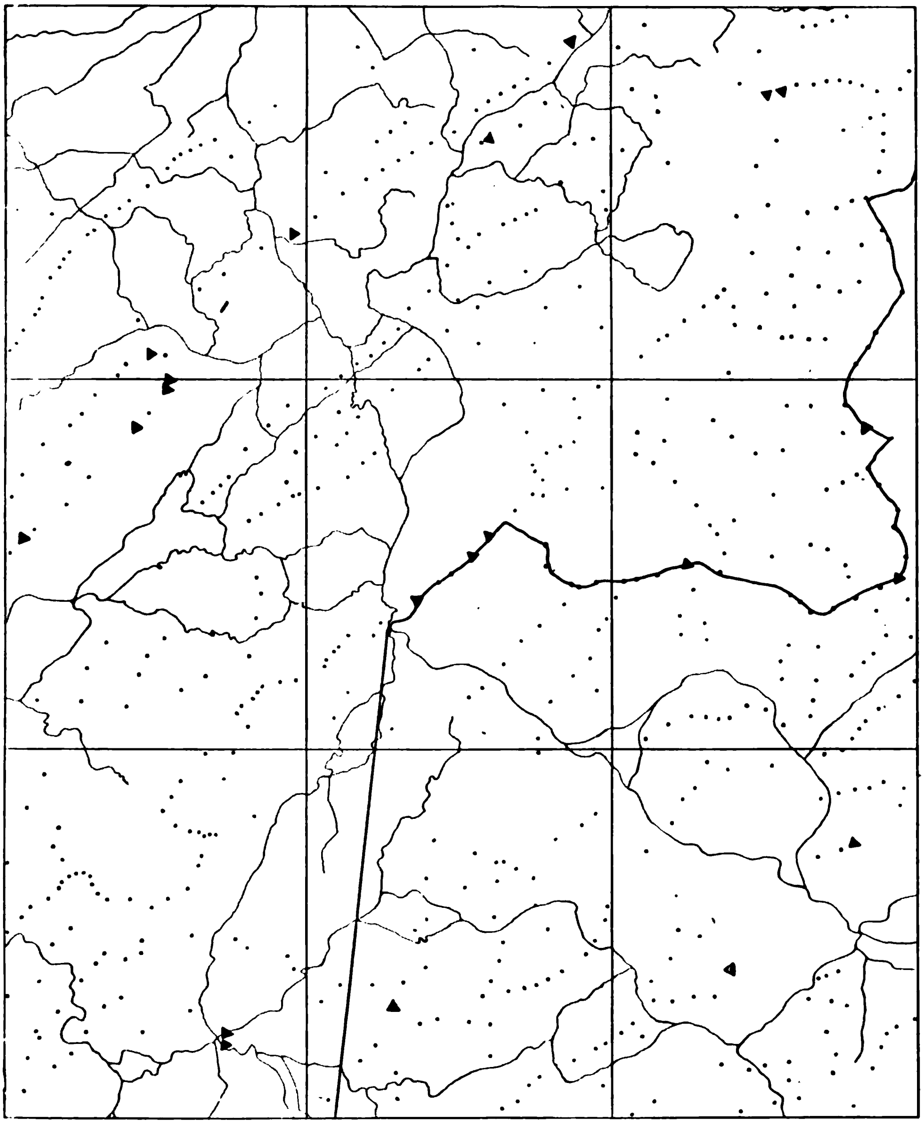
During the winter the co-ordinates of the points fixed on the crests of the falls have been computed and it is expected that the results of the survey will soon be ready for publication. It may here be stated, however, that the average rate of recession along the whole crest line of the Horse Shoe fall has been about 2.4 feet a year since 1842; in the central portion of the channel the rate has been about twice as great. The recession of the American fall during the same period has been slight.

In connection with this subject I would call attention to the desirability of having surveys of the falls made hereafter at regular intervals of ten or fifteen years. The cost of such surveys will be small; the results will always be of general interest, and they may not improbably be of great value to the geologist and engineer.

The Survey is indebted to the officials of the State reservation at Niagara, and especially to Hon. T. V. Welch, superintendent, for courtesies extended to us while engaged in this work at the falls. My thanks are due Mr. P. C. Warman, who was temporarily assigned from Mr. Gilbert's party to my assistance in making the survey. His aid greatly facilitated the work.

GEOLOGICAL INVESTIGATIONS.

As stated in your report for the preceding year, many questions arise in carrying on investigations undertaken by the geologists of the Survey which require for their elucidation applications of some of the more technical branches of mathematics. Among the questions



STATIONS — ▲ LOCATIONS BY INTERSECTION — • TRAVERSE LINES ～

INSTRUMENTAL CONTROL OF TOPOGRAPHY IN TENNESSEE AND NORTH CAROLINA MURPHY SHEET.

of this class to which, at your request, I have devoted considerable attention are the following:

(1) The form and position of the sea level of the earth as dependent on superficial distributions of matter.

(2) The problem of a heated sphere presented by the earth, the consequent distribution of internal temperatures, the slow cooling by conduction, and the resultant contraction, with its effects.

(3) The distribution of density and pressure within the earth, their relation to each other and to the heat conducting properties of the earth's mass.

(4) The stresses and strains of the earth's crust, its deformation within the limits of elasticity, and the causes and effects of crustal movements.

My investigations of the first of the above questions were begun as private studies some years ago, but they were renewed in 1885, at the request of my colleagues, Messrs. Gilbert and Chamberlin, for the purpose of solving certain problems arising in their geological researches. Although designed to meet the requirements of these special problems, the analysis which I have developed is much more comprehensive, including, in fact, the entire class of problems to which they belong. This work was completed during the year and presented for publication in the form of a bulletin. It is hoped that the results attained and the processes employed will be of interest and value both to geologists and geodesists. Certain numerical results of the work, pertaining especially to Professor Chamberlin's problem, are incorporated in his "Preliminary paper on the driftless area of the upper Mississippi valley," in the Sixth Annual Report of the U. S. Geological Survey.

The last three of the questions enumerated above are fundamental and among the most difficult with which physical geology has to deal. Rapid progress towards their elucidation can hardly be expected, but it is hoped that prolonged study will remove some of their difficulties and at least indicate the routes which must be pursued to reach complete solutions. Thus far my success has been greatest in treating the problem of the earth as a cooling sphere. A paper on this subject, which, it is believed, will be of interest to geologists and physicists, is in preparation and will be ready for publication at no distant date.

Although my studies of these more abstract questions can only be said to have fairly begun, owing partly to the limited time afforded for their consideration by the intervals in my other occupations and duties on the Survey, I feel warranted in saying that the difficulties to be overcome are largely such as will require extensive additions to our experimental knowledge of the properties of terrestrial rocks and materials. Anticipating a special report on our needs in this respect, I may here state what the most important of those properties are. For all of the principal rocks we ought to know—

(1) The coefficients of expansion and their variations with temperature;

(2) The specific heats and their dependence on temperature and pressure;

(3) The specific conductivities and their relations to temperature and pressure;

(4) The principal moduluses of elasticity; and

(5) The limits of pressure and temperature at which their structural characteristics break down.

The necessary experiments for the determination of some of these properties have already been undertaken, I believe, in the division of chemistry and physics, and I entertain the hope that means may soon be available for determining all of them.

Very respectfully, your obedient servant,

R. S. WOODWARD.

Hon. J. W. POWELL,
Director U. S. Geological Survey, Washington, D. C.

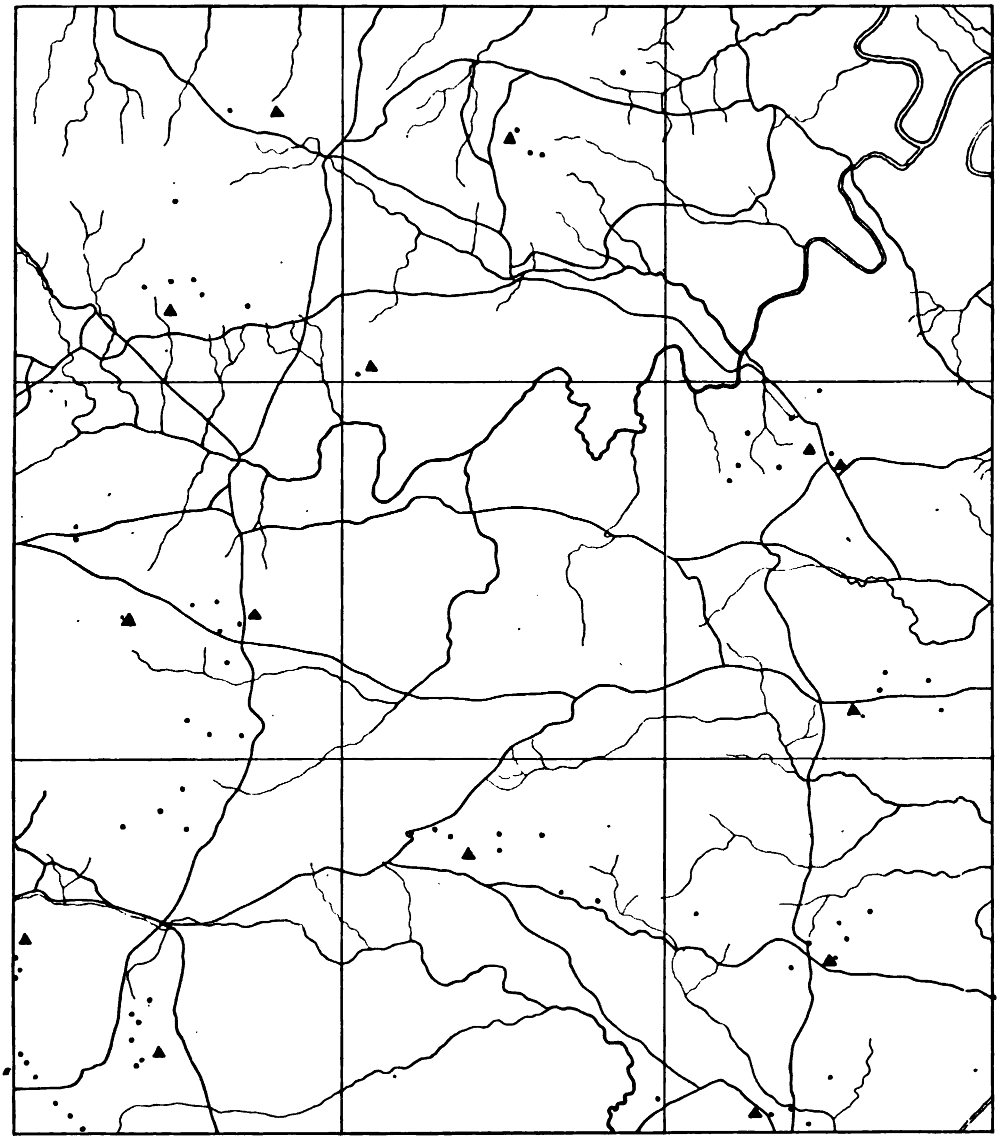
REPORT OF PROF. RAPHAEL PUMPELLY.

DEPARTMENT OF THE INTERIOR,
U. S. GEOLOGICAL SURVEY,
DIVISION OF ARCHEAN GEOLOGY,
Dublin, N. H., July 1, 1887.

SIR: During the year my division has been at work on New England geology, and in this chiefly on the structure of the Green Mountain system. The progress made towards the solution of this complicated problem has been such that I confidently expect to finish it this season and have the results ready for publication this winter in the form of a map and sections showing in detail the geology from the New York line to the eastern side of the Hoosac mountain. The white gneisses, quartzite, and conglomerates will be shown to be the representatives on the Hoosac mountain of the quartzite that conformably underlies the Stockbridge limestone, and the schists and gneisses of the top and west flank of Hoosac mountain will be shown to be equivalents of the Taconic schists which overlie the Stockbridge limestone and form the Taconic range.

The greatest difficulty we have had to overcome has been to discover the cause of the rather sudden disappearance of the limestone from the series as, in going east from the newer members, we rise into the older or Hoosac members.

I expect to present at the end of this season a satisfactory demonstration of the cause of the disappearance of this limestone as such. The impossibility of working out the obscure structure of this mountain system by cross sections alone has necessitated studying in detail the areal geology of considerable districts, and we have now nearly finished a geological map of the northern half of Berkshire county



STATIONS—▲ LOCATIONS by INTERSECTION—• TRAVERSE LINES

INSTRUMENTAL CONTROL OF TOPOGRAPHY IN TEXAS; BLANCO SHEET.

based on a study of the character and structural phenomena of practically every outcrop within that area.

A great deal of reconnaissance work has been done by my force outside of this area for comparative sections, all the way from West Point on the Hudson to Rutland, Vt.

I expect this season's work to give us an insight into the geological relations of the Hoosac rocks to the so-called overlying "calciferous mica schist," and perhaps also to the fossiliferous rocks of Bernardston. In either event we shall then be able to move our field of study rapidly northward to attack the problems of structure and relative age of the White Mountain mass.

At the same time the mapping of the areal geology of Massachusetts can be pushed forward rapidly, our work having furnished the key for the Green Mountains and the extensive work of Prof. B. K. Emerson having placed him already in a position to map a large portion of the central part of the State east of the Hoosac range.

In the distribution of the members of my division the work on Hoosac mountain was done by Messrs. Wolff and Putnam until the death of the latter last October, and since then by Mr. Wolff alone; Mr. Pierce made a large scale topographical map of the west flank of Hoosac mountain as a basis for mapping the intricate geology of that area.

The work on the Greylock mass was executed last year by Mr. Dale, assisted by Mr. Hobbs, and this year since May 1 by Mr. Dale alone.

In prosecuting our work the first year, before the excellent maps had been made by the topographical department, we were delayed by the necessity of making our own instrumental survey and map.

I have the honor to be your obedient servant,

RAPHAEL PUMPELLY,
Geologist in Charge.

Hon. J. W. POWELL,
Director U. S. Geological Survey, Washington, D. C.

REPORT OF MR. N. S. SHALER.

DEPARTMENT OF THE INTERIOR,
U. S. GEOLOGICAL SURVEY,
DIVISION OF COAST LINE GEOLOGY,
Cambridge, Mass., July 1, 1887.

SIR: I have the honor to submit the following summary report concerning the work of the Survey in my division for the fiscal year ending June 30, 1887.

During the month of July I was occupied in preparing a plan for the study of the fresh water swamps of this country. The novelty of this inquiry, together with the probability that it would in the

course of time call for a considerable expenditure of money, made it desirable that I should ascertain with care the character of the work which it would be advisable to undertake. With this view I visited several of the more important swamp areas of New England, as well as certain characteristic areas in central New York. I had previously made a careful reconnaissance of our southern swamps.

The amount of money allotted to my division made it impossible for me to undertake any very extensive surveys of our swamp regions, but during the year I was able, with the aid of my assistants, to begin such work on the swamp areas of Massachusetts and of Maine. For the guidance of this work and as a result of practical observations on a considerable variety of our inundated lands, I have prepared a report containing directions for the information of those who are to have charge of such surveys.

In the latter part of August I visited the region in the neighborhood of Frenchman's bay, on the coast of Maine, in order to carry forward some studies on the elevated coast lines of that region and to make ready for the preparation of a report on the island of Mt. Desert and the neighboring shores. This work had been begun during the preceding summer, but was left incomplete at the close of the field season. The studies made on this journey served to confirm the opinion which I had formed during the preceding season of work and to assure me that there were marks of marine action on the mountains of Mt. Desert indicating that the sea since the close of the last glacial period has stood at various heights above the present level up to more than a thousand feet above its actual position.

During the month of September I was engaged in an effort to extend these observations on the old sea levels to the mountains of New Hampshire. A tolerably careful reconnaissance of those elevations seemed to show that the marks of marine action which were found at Mt. Desert do not occur there. It seems likely from the data obtained that the hill country of New Hampshire retained its covering of ice until the region had been to a great degree elevated above the level of the sea.

In the months of October, November, and December I was engaged on the study of the shore line phenomena of southeastern New England between the mouth of the Merrimac and Narragansett bay. This work, as will be shown in reports now in preparation, has served to extend our knowledge of the history of this part of the Atlantic coast. During the winter season I was engaged in the preparation of reports on the islands of Mt. Desert and Nantucket. The report on Nantucket was transmitted to the office in the month of May last.

In the month of June I found it necessary again to visit Mt. Desert in order to complete the report and the accompanying maps

of that district, which I have forwarded to you for publication in the present volume.

During the year I have had the help of two permanent assistants, Messrs. Collier Cobb and Robert Robertson. Mr. Cobb has been employed in the service of the Survey since December last. A portion of his time has been devoted to an extended system of correspondence with persons in this country who have an economic or scientific interest in our inundated lands. His object has been to secure a preliminary acquaintance with the extent and distribution of the swamps in our Southern States and also to ascertain the results of experiments which have been made for their improvement. As Mr. Cobb is to be engaged in survey work on these swamp areas during the coming fiscal year, he has devoted a portion of his time to a study of our swamp areas in eastern Massachusetts especially adapted to making him familiar with researches of this character. During the portion of the winter which was unfit for field work he was employed in a careful study of four diamond drill borings, each represented by a core about 1,000 feet in length, from the Narragansett coal field. As these sections give us knowledge of beds containing considerable amounts of coal which are not otherwise open to observation, it seemed desirable to have the sections very carefully delineated and studied with the use of the microscope. As soon as the topographical maps of the Narragansett coal field are available, as they will be within a year from the present time, I purpose to prepare a report on the geology of that district, for which the notes are now well in hand.

Mr. Robertson came to me on the 1st of February last. Since that time he has been mainly engaged in certain chemical work in connection with my field studies. He has prepared in this time two considerable reports, one concerning the distribution of magnetic oxide of iron in the deposits of drift left in New England by the last glacial period. The result of his study is to show a remarkable concentration of this material in the drift accumulations. Another inquiry carried on by Mr. Robertson has shown me, what I had suspected from other sources of information, that a certain quantity of sea water remains imprisoned in some of our stratified clays formed at the close of the glacial period but now lying at various heights above the sea level. Special reports concerning these two inquiries are now in preparation and will probably be published during the coming year.

Besides the reports above mentioned, several others containing the results of labor done during the last fiscal year or in previous seasons have been made ready for publication. Two of these, one on "The geology of Cobscook bay, in the State of Maine," another on "The fluviatile swamps of New England," were published in the American Journal of Science. An extended report on the bowlder

train from Iron Hill, in the town of Cumberland, R. I., is now ready for the press and awaits your order.

In addition to the aid which I have secured from the abovementioned assistants, I have from time to time received valuable help in field work and laboratory researches from Messrs. T. W. Harris, R. S. Tarr, and W. F. Gahong.

Very respectfully, your obedient servant,

N. S. SHALER,
Geologist in Charge.

Hon. J. W. POWELL,
Director U. S. Geological Survey, Washington, D. C.

REPORT OF MR. G. K. GILBERT.

DEPARTMENT OF THE INTERIOR,
U. S. GEOLOGICAL SURVEY,
APPALACHIAN DIVISION OF GEOLOGY,
Washington, D. C., July 1, 1887.

SIR: I have the honor to submit the following report of work in my division during the fiscal year ending June 30, 1887.

The general plan of work in the Appalachian division was described in my last annual report. It includes initially the study by my assistants of the structure and stratigraphy of four narrow belts of country, each crossing the Appalachian mountains and the great Appalachian valley, and the study by myself of the later geologic history of the region.

My own field work continued the study of changes of altitude in the Ontario basin, and, as heretofore, was devoted especially to the tracing and measurement of ancient shore lines. It was also carried with similar methods into the basin of Lake Erie, and special attention was given to the history of the Niagara river and Niagara falls. In this latter work I co-operated with Mr. R. S. Woodward, who made a new map of the falls for the purpose of demonstrating their rate of recession. These researches occupied about three months' time, falling within the calendar months of July, August, and September, 1886, and June, 1887. A reconnaissance was also made in March and April, in company with the Director of the Survey, for the double purpose of studying certain problems in surface geology and planning future work in the southern Appalachian regon. The remainder of the year was spent in Washington, partly in researches of a literary nature arising from the field studies just mentioned, partly in the preparation of manuscript for the still unfinished report on Lake Bonneville, and partly in various administrative duties.

The four belts selected for special study in the Appalachian field are called the Potomac, the Greenbrier, the French Broad, and the

Alabama, and this enumeration gives their order from north to south. That of the Greenbrier still remains untouched.

Mr. Bailey Willis continued field work in the division of the French Broad, stopping for the winter about the middle of October and resuming early in June. The method of work developed by him employs the stadia transit as a principal field instrument. A reconnaissance of the region having been made and the best lines for the measurement of geologic sections determined, a stadia traverse survey is made of each of these lines. This survey determines a series of stations, giving for each the distance and the direction from the preceding station and the difference of altitude. At the same time the strike and the dip of the rocks are observed and their characters are described. The topography immediately adjacent to the line is sketched, so that the work can be finally fitted into the general topographic map, which, being on a comparatively small scale, exhibits less detail. In the office the routes of survey are platted, together with observations on dip and strike, profiles are constructed, and by means of a system of graphic construction all the data are projected from the meandering line of traverse onto the same vertical plane. In this way are assembled the data for both structural and columnar sections. Mr. Willis has given attention to problems connected with the complicated folds and faults of his district, and especially to the considerations which should guide in the inference of underground structure from superficial observations of dip and rock texture. He has also studied the relation of the drainage system to the rock structure and of the modifications of drainage during the progressive degradation of the country. In connection with these studies he has prepared a wax stereogram representing the structure of a portion of his district and has written an essay on the drainage system of Bay's mountain, Tennessee, which, with official permission, was published in The School of Mines Quarterly. He has also prepared a short paper entitled Changes in River Courses in Washington Territory Due to Glaciation, which is published as a bulletin of the Survey.

Mr. I. C. Russell, continuing work on the Alabama belt, kept the field last year from July to October, inclusive, and resumed it on the 10th of April. His field methods are essentially identical with those of Mr. Willis and his survey of the belt is now nearly completed. During the winter he revised for publication a paper which appears in this volume, on the "Quaternary history of Mono valley," and another on the "Subaërial decay of rocks and the origin of the red color of certain formations," which will appear as a bulletin. During the year his monograph on Lake Lahontan was published.

The remaining belt, that of the Potomac, is being surveyed by Mr. H. R. Geiger, who continued in the field last year until the 20th of November and returned to it on the 6th of May. His method of field

work likewise includes the survey of traverse lines, but he does not employ the stadia. Upon wagon roads he uses the odometer for distance, and, where the wagon cannot be taken, a tape line. His directions and angular altitudes are determined by the aid of the altazimuth. Having begun his survey near the western line of Maryland, he has now brought it to the western margin of the great Appalachian valley in the vicinity of the Massanutten mountains.

During the winter months each of these gentlemen prepared structural and columnar sections and performed the other work necessary to make the work of the preceding summer a matter of office record. The publication of their work is deferred until the three surveys shall have reached such a stage that their results can be advantageously compared and combined.

Mr. N. H. Darton spent the months of July, August, and September in New York and New Jersey, continuing a study begun by him previous to his connection with the U. S. Geological Survey. It comprises a detailed examination of the Triassic rocks and associated traps in northern New Jersey and the adjacent portion of New York. During the remainder of the year his labors have been almost entirely bibliographic. The subject bibliography of Appalachian geology mentioned in my last report has been continued and somewhat enlarged in scope, so as to give separate reference to geologic sections. The principal body of official literature has now been covered, and it is estimated that more than one-half of the serial literature has been searched. The total number of bibliographic cards is about eleven thousand. Previous to his connection with the Survey, Mr. Darton had begun and nearly completed a list of American papers on geology published in scientific serials. This he has now carried forward with enlarged scope, and it will shortly be offered for publication as a bulletin of the Survey. Mr. Darton has also prepared a bibliography of North American geology for 1886, which has been accepted for publication as a bulletin and is now in press.

As previously announced, Prof. I. C. White, of the University of West Virginia, has been for some time engaged in the preparation for the Survey of an essay on the comparative stratigraphy of the bituminous coal fields of Pennsylvania, West Virginia, and Ohio. During the last fiscal year he has received no compensation from the Survey, but has nevertheless continued the work both in field and in office so far as his other engagements permitted. At his request, the completion and publication of the essay have been still further postponed, so that it may have the advantage of yet additional field observations.

The publication in this report of the map of the Mono basin prepared to accompany Mr. Russell's paper and the probability that this map will be used in subsequent compilation render it proper to place on record the method of survey. The field work was executed

by Mr. Willard D. Johnson in the summer of 1883, his principal instrument being the plane table and his method that of intersection. No base line was measured, the work being initiated by assuming the positions of two peaks and marking them upon the plane table sheet. Subsequently three geodetic points of the transcontinental belt of the U. S. Coast and Geodetic Survey were included in the graphic triangulation of the plane table. The co-ordinates of these points were afterward furnished by the Coast and Geodetic Survey, and their employment gave to the Mono map its scale, its geodetic position, and its orientation. A system of relative altitudes was determined by angular elevations with the alidade and to this were added a few determinations by aneroid barometer. The system was connected with one of the geodetic stations of the Coast and Geodetic Survey, and through this means all altitudes of the map were based upon an initial point furnished by that survey. The soundings of Mono lake were made by Messrs. Russell and Johnson from a boat, whose positions were determined by simultaneous observations with two plane tables on land.

The work of the division has been materially advanced by Messrs. C. D. Walcott and H. S. Williams, who have kindly examined the paleontologic collections; by Messrs. Cooper Curtice and R. R. Gurley, who each spent several weeks in Mr. Willis's field, studying the paleontology and stratigraphy of the Knox shales in co-operation with him; and by Mr. J. S. Diller, who has had numerous rock specimens prepared for microscopic study and has freely given us the benefit of his skill in lithology.

Mr. Ira Sayles, who had previously executed field work in this division, handed in a manuscript report for office use and was afterward assigned other work by the Director. Mr. William P. Trowbridge, jr., acted as volunteer assistant to Mr. Willis until the end of July, when he was compelled by illness to return home. Mr. Willis is at present aided by Mr. Arthur Keith, who reported for duty on the 15th of June. Mr. Russell was ably assisted in field and in office by Mr. H. J. Biddle, who remained with him during the first half of the fiscal year and then resigned. The services of Mr. C. W. Hayes were afterward engaged, and he reported for duty about the middle of April. Mr. Albert L. Webster acted as volunteer assistant to Mr. Russell during the first half of July, 1886. Mr. Geiger was assisted by his son, Mr. F. W. Geiger, from July to November, inclusive. Mr. Darton while in the field was favored with the volunteer assistance of Mr. F. M. Smith. Mr. R. B. Cameron, detailed from the division of geography, rendered efficient service from the middle of October to the end of the fiscal year. He assisted Messrs. Willis and Geiger in the platting of traverse notes and the construction of sections and afterward took the field with Mr. Geiger. Mr. Basil Duke, jr., likewise detailed from the division

of geography, gave clerical help to Mr. Darton from December 15 to May 30, and several other details of similar nature were made for shorter periods. Mr. P. C. Warman, detailed from the central office, assisted me in the field during a part of July. Mr. Robert Stein, acting as my stenographer and general clerk, has likewise co-operated with my assistants and has proved especially useful by reason of his skill as a translator.

During the field season Mr. Willis and Mr. Russell, subsisting on rations, have each given continuous employment to a cook and a teamster.

I am, with great respect, your obedient servant,

G. K. Gilbert,
Geologist in Charge.

Hon. J. W. Powell,
Director U. S. Geological Survey, Washington, D. C.

REPORT OF PROF. R. D. IRVING.

Department of the Interior,
U. S. Geological Survey,
Lake Superior Division,
Washington, D. C., July 1, 1887.

Sir: I have the honor to submit the following report of the operations of the division of the Survey under my charge for the year ending June 30, 1887.

As shown in former annual reports, the work set for this division includes especially a study of the great formations which lie beneath the Potsdam or basal Cambrian sandstone of the Northwestern States. The final object of this study is the preparation of a series of sheets for the great geological map of the United States called for by the organic law of the Survey. In order, however, that each color on these sheets shall cover rocks which are in some sort homogeneous and chronologically equivalent, a necessary preliminary to the mapping has been the ascertaining of the true chronological succession, or natural classification, of the pre-Cambrian formations of the region. These formations had been so inadequately studied that the various geologists who in former years had occupied themselves with them, having confined their researches to restricted and disconnected areas, had failed to reach any such general agreement or to accumulate such a mass of trustworthy material as would warrant the adoption by the Survey of any final classification that had previously been suggested. As indicated in my last annual report, however, in the several years that have elapsed since the beginning of our investigation in September, 1882, we have made such progress towards a final classification that, while I have felt it necessary

to continue the special studies throughout the year just closed, I have also thought it wise to devote part of the force to the completion of the geology for the final sheets. These sheets are bounded by the whole-numbered parallels of latitude and longitude, and comprise each one square degree. As a topographical basis for them we have at present only the surveys of the U. S. Land Office, except near the shores of Lake Superior, where the exceedingly accurate maps of the U. S. Engineer Office are available. For special purposes further topographical mapping will be needed, but for the outlining of the grander geological phenomena, such as will be given on the general map referred to, it is not thought that additional work of this kind will be necessary. Moreover, if such further topographical work should be deemed necessary for the sake of uniformity in the elaboration of the sheets of the final map, it can be done as well after the geological mapping as before, our geological boundaries being located by measurements from section corners. In our preliminary studies we have gathered material sufficient to do much of the final mapping ; but since in the field work for these preliminary studies it has been designed to follow the most instructive routes and to study the most characteristic exposures, rather than to cover the whole territory, various insufficiently examined areas have been left. The general structure of these areas is pretty well known, but our knowledge of them is not sufficient to allow of mapping. It has been my plan, then, while continuing our special studies, to proceed also with the detailed examination of these unfilled gaps in such order that the geology of the several sheets for which the Lake Superior Division of the Survey is responsible shall be completed sheet by sheet.

FIELD WORK.

The field work of the year has included, then, a continuation of the special studies preliminary to mapping, and the mapping itself. In the former work I have myself been more especially engaged, as have also Professors C. R. Van Hise and G. H. Williams ; while Messrs. W. N. Merriam and W. S. Bayley have given their attention more particularly to mapping.

Besides visiting Dr. Williams's party in the field and planning in detail the routes to be followed, and work to be done by each of the field parties, my own field work has consisted of an especial study of the contact relations of the Huronian series, as outlined in my last annual report, with the pre-Huronian basement crystallines. In this study I have been accompanied and aided constantly by Professor Van Hise. Our first examinations were made, at our own expense, along the line of an unused branch of the Canadian Pacific Railway running from Algoma Mills, on the northern shore of Lake Huron, to Sudbury, on the main line of that railway, and thence eastward along the main line as far as Whitefish river, on the east. The area

examined adjoins directly that mapped originally by Logan and Murray as Huronian on Plate III of the Atlas of the Geology of Canada. This original Huronian area extends along the northern shore of Lake Huron between the St. Mary's and Thessalon rivers, continuing also much farther east a short distance back from the coast line. My report for the year 1883, as also my preliminary paper published in the Fifth Annual Report of the U. S. Geological Survey, will show that I examined this area closely in that year as a necessary beginning to our whole investigation. The original Huronian series was then found to be, as described by Logan and Murray, a great succession of gently bowed and not greatly altered fragmental rocks, with some interbedded eruptives, resting in strong discordance upon a much more ancient basement of crystalline schists, gneiss, and granite, fragments of which rocks occur in the overlying fragmentals and in especial abundance at the contacts of the two sets of rocks. But besides this typical Huronian area, the maps of the Canadian survey, from Logan's time down, and more particularly in later years, have mapped as Huronian large areas about which very little is accurately known. To judge from the descriptions of the Canadian reports, as well as from what I had myself seen in these areas from time to time, they contain at least some rocks which are not really classifiable with the typical Huronian series. The further progress of our work seeming to demand more definite knowledge as to these doubtful Canadian areas, I selected for examination that extensive so-called Huronian area which is made on the Canadian maps to extend from the vicinity of the north shore of Lake Huron far to the northeastward, with an immense surface spread, and to be actually continuous with the typical district already referred to as shown on Plate III of the Atlas of the Geology of Canada. This particular area was selected partly on account of this continuity and partly because it is traversed from southwest to northeast by the railroad line above mentioned, which is just about 100 miles in length and is flanked by numerous bold rock exposures. Traveling by hand car, we were enabled to make our examinations rapidly and at the same time to see the ground thoroughly. As was anticipated, this so-called Huronian area was found to include two distinct sets of rocks, the one a fragmental series equivalent to and in fact continuous with the typical Huronian region to the west, and the other made up of crystalline schists and gneiss with great intrusions of granite; fragments of the granite, gneiss, and schists occurring abundantly in the overlying fragmental series at and near the contacts.

This examination was made in the first half of August. The latter half of this month and the first half of September were devoted to a study of the contacts of the iron bearing fragmental series of the Marquette region with the basement schists, gneiss, and granite.

Here the newer fragmental series is folded in with the basement rocks, its layers usually dipping at high angles; and not unnaturally the schists of the basement have been regarded as Huronian and as part of the same series with the overlying fragmentals, even by those who have looked on the gneiss and granite as pre-Huronian. But these schists are penetrated by the granite, which yields fragments, as do also the schists it intersects, to the fragmental or true Huronian series above, a number of contact conglomerates having been found by us along the line of junction of the two sets of rocks.

In my last report it was stated that during the fiscal year then closing Dr. Geo. H. Williams, of the Johns Hopkins University, made under my instructions a detailed petrographical study of the peculiar schistose rocks which are exposed at the several falls of the Menominee river, on the boundary between Wisconsin and Michigan. This study was made with the object of determining the origin of the schists referred to, such a determination having an especial importance, inasmuch as this class of rocks is very widely spread throughout the Lake Superior region. Dr. Williams's results show very definitely the correctness of the suspicion which presented itself to me some years ago, when examining these rocks on the ground, viz, that they are derivatives from acidic and basic eruptives. It being thought desirable that at least one other area of similar rocks should be studied before publishing his results, Dr. Williams was instructed to examine carefully (collecting plentiful material for a laboratory study) the belt of greenish schists, greenstones, and associated rocks which extends westward from the shore of Lake Superior, near Marquette. His instructions called for the making of detailed sections across the belt as follows: (1) Along the shore of Lake Superior from the mouth of Dead river to the mouth of Carp river; (2) along a line running about two miles west of Marquette and following the western sides of sections 10, 15, 22, and 27 of township 48 north, range 25 west; (3) along a line lying just east of Negaunee and running through the middle of sections 4, 9, 16, 21, 28, and 33 of township 48 north, range 26 west; (4) along a line running northward from the east end of Teal lake and following the middle line of sections 1, 12, 13, 24, 25, and 36 of township 48 north, range 27 west. This work was accomplished by Dr. Williams, with the aid of Dr. W. S. Bayley, between July 12 and August 8, in accordance with the instructions.

My last annual report showed that the field work in that part of Minnesota which lies between the national boundary line, from the Lake of the Woods to the mouth of Pigeon river, on the north, and the coast of Lake Superior and the line of the Northern Pacific railroad as far west as the Mississippi river, on the south, had then progressed sufficiently to warrant a first general account of its structure. Such an account, with map, is given, very briefly, in my paper on the pre-

Cambrian formations in the same volume. However, although the general structure was made out, there still remained areas to be examined. To this work Mr. Merriam, provided with detailed instructions, devoted himself continuously between August 5 and October 17. His party included (besides three and sometimes four packers) field assistant W. S. Bayley, until September 21, and volunteer assistant G. M. Buckstaff, who served through the season without compensation or defrayment of expenses beyond the camp board. Mr. Merriam's first trip was from the village of Tower, on the south side of Vermilion lake, via Vermilion river, to Pelican and Nett lakes. Returning to Tower, a second start was made on the 21st of August. His route lay now eastward, through Vermilion, Mud, Burntside, and Long lakes, to Falls lake, where the party was divided into two, one making a trip south through White Iron and Birch lakes to Greenwood lake, in township 58 north, range 10 west (unsurveyed), and the other, under Mr. Bayley, examining in detail several places in the vicinity of Falls lake. Returning from the Greenwood lake trip, which occupied ten days, the two parties united again at Falls lake and proceeded eastward along the national boundary as far as Sasaganaga lake, where a turn was made to the south, through Red Rock, Island, and Sea Gull lakes, to Ogishkimanissi lake, trips being made inland for short distances from each of these lakes. Leaving Ogishkimanissi lake, the route lay east, through townships 64 and 65 north, ranges 6, 5, and 4 west, to the west end of Gunflint lake, and from here along the boundary to Rove lake, which was reached September 20. Here the party divided for the remainder of the season, Mr. Bayley, with one man, proceding via Grand Marais to Duluth and thence to the Cloquet river and Mesabé range, as explained below. After obtaining additional supplies from Grand Marais, Mr. Merriam, with the remainder of the party, returned to the western end of Gunflint lake, for the purpose of making a further examination of township 65 north, range 4 west. This completed, he turned again eastward along the boundary, which was followed as far as South Fowl lake, from which point a side trip was made on foot, southward along the line between ranges 3 and 4 east, for about six miles, then west across range 3 east, and then north and east to South Fowl lake again. Thence the route was down Pigeon river to Grand Portage, on the Lake Superior coast, which was reached October 17. Proceeding next via steamer to Grand Marais, the party was finally disbanded, and Mr. Merriam returned via Duluth to the office at Madison, Wis., reaching that place October 22. During the season Mr. Merriam traveled 500 miles by canoe, without counting minor turns, collected 250 specimens, and took 110 photographic negatives, besides making full notes of his observations.

In addition to the work accomplished by him, as above explained, Mr. Merriam's instructions called for certain examinations in the vi-

cinity of the Cloquet river and along the so-called Mesabé range from the line of the Duluth and Iron Range railroad to the Mississippi river; but it was left open to him to divide his party and assign these examinations to Dr. Bayley in case it should become evident that all the work laid out could not be completed by one party before the close of the season. Accordingly Dr. Bayley left Mr. Merriam September 20, as above stated, proceeding via Grand Marais to Duluth. Here the necessary provisions were procured for a canoe trip via the St. Louis and Cloquet rivers to the eastern line of township 52 north, range 17 west, and thence on foot southward to a large ledge described in the field notes of the United States surveyor as occurring in the northwestern part of township 51 north, range 16 west. The examination of this place was thought important because of the extreme rarity of exposures in the region of the lower Cloquet, the drift covering being very general and heavy. Unfortunately the supposed exposure turned out to be a heap of erratics only. Returning to Duluth, Mr. Bayley next transferred his party, consisting of himself, two woodsmen, and two packers, via the Duluth and Iron Range railroad, to the Mesabé range, in township 60 north, range 15 west. This range is a ridge of granite lying just north of the northern edge of the flat lying Animiké slates, as described by me in former reports. Mr. Bayley then followed this range westward, traveling along section lines in such a manner as repeatedly to cut the boundary between the Animiké slates and the granite and that between the granite and the schistose rocks farther north, the location of which boundaries was the especial object of the trip. The granite exposures along the main range are quite numerous, but those of the rocks on either side of the granite are much rarer. However, enough were found to establish satisfactorily the boundaries desired, as also to throw light on the structure of a district hitherto wholly unexplored by the geologist. The party reached Grand Rapids October 24, the time from which date to November 3 was devoted to searching for exposures throughout the drift covered country north and northeast of Grand Rapids. Leaving Grand Rapids November 3, the party proceeded via the Mississippi river to Aitkin and by rail to Duluth, where it was disbanded, Mr. Bayley reporting at the Madison office November 8.

The only field work undertaken between the opening of the season of 1887 and the date of this report has been by a party under the charge of Dr. W. S. Bayley, the object being the mapping of certain insufficiently known areas in the northern peninsula of Michigan, as above explained. The area especially assigned Dr. Bayley is bounded on the north by the coast of Lake Superior between L'Anse and Marquette and on the south by the line of the Marquette, Houghton and Ontonagon railroad between the same points. It includes the Huron mountains and in large part has never been geologically examined, though of late years Mr. C. E. Wright, State geologist of Michigan,

has begun here some very detailed studies. Dr. Bayley is furnished with very full instructions and with maps showing the exact lines which he is expected to follow. His party includes two woodsmen and two packers, a division of the party being made each day for the purpose of traversing as many miles of line as possible. Dr. Bayley left Baltimore May 6, and, having organized his party and obtained his supplies at Marquette and L'Anse, Mich., began work in the vicinity of the latter place May 10. When last heard from he had traversed the lines marked for him in township 50 north, ranges 30, 31, and 32 west; township 51 north, ranges 29, 30, 31, and 32 west; and in township 52 north, ranges 29, 30, and 31 west—having followed in all about 200 miles of line.

OFFICE WORK.

As in last year's report, I may conveniently classify the office work of the year under the heads of petrographic studies, mapping and drafting, photography, and publications.

Petrographic studies.—From the nature of the rocks which make up the formations we have to examine, it results that micro-petrographical investigations form a very important part of the office work of the division. This work indeed is steadily increasing in relative amount, being necessary not only in the case of especial studies designed to elucidate the origin of the different kinds of rocks but as a constant concomitant of the field work in the correlation of exposures. In the latter case the studies of thin sections do not need to be so exhaustive; but, since practically all specimens gathered must be sectioned and examined, the aggregate amount of such work in each year becomes very great. During the year just closed, in addition to what I have done myself, petrographical studies have been carried on by assistant geologists Van Hise and Williams, field assistant Bayley, and Miss Florence Bascom, a volunteer assistant.

My own studies have been partly in connection with the preparation of the memoir on the Penokee-Gogebic iron region, partly in connection with my field work of the year, as above described, and partly in connection with a general comparative study of the characteristic rocks of all the Huronian areas of the region under examination.

Professor Van Hise's microscopic studies, prosecuted at the University of Wisconsin, have consisted mainly of a general revision of all the work previously done in connection with the volume on the Penokee-Gogebic region, in which revision a large amount of new material was included.

Dr. Williams's work, done at the Johns Hopkins University, Baltimore, has been the continuation of the exhaustive study, begun by him in the previous year, of the peculiar greenish schists and associated rocks so largely developed in various portions of the Northwest and forming so important an element in the make-up

of the great pre-Huronian or Archean basement, the object of which study has already been explained. In addition to the collections gathered by him in 1885 on the Menominee river, Dr. Williams has had during the past winter those collected by him in the summer of 1886, as above indicated. He has also had for comparison a large suite of similar rocks collected by Mr. A. C. Lawson in the region of the Lake of the Woods, Canada. All these collections are fully sectioned. He has also been furnished, for the furtherance of his work, with a number of chemical analyses, made in the laboratory of the Survey at Washington. Dr. Williams's results are satisfactory, and, although the adequate elaboration of them for publication is necessarily a slow process, involving as it does many careful drawings, he is well advanced with the manuscript of an account of these results, to be published as a bulletin of the Survey.

Dr. Bayley's work, done mostly at the University of Wisconsin but partly at the Johns Hopkins University, has been the continuation of the study of the large collections made by himself and Dr. Williams on Pigeon Point, Minn., in 1885. As explained in my last annual report, the Pigeon Point locality was selected for study as displaying on a large scale an extraordinary association of sedimentary and eruptive rocks, with striking contact phenomena, such as obtain at numerous points in northeastern Minnesota but are nowhere else so favorably situated for study. Dr. Williams, finding his hands full with the other work assigned him, with my consent resigned the elaboration of the Pigeon Point results to Dr. Bayley, who had been engaged on them as assistant to Dr. Williams from the beginning. The problem proves to be a much more complicated one than was supposed, involving most singular contact phenomena with two kinds of sedimentaries of two wholly different eruptives, the one a highly basic gabbro, the other a very acid granite. Strangely enough, the contact results seem to be much the same in all cases. A large number of chemical analyses have been made at Washington to aid Dr. Bayley, and, although some satisfactory results appear to have been obtained, we feel that more must be done before publication will be warranted.

The work of Miss Bascom, an advanced student of the petrographical laboratory of the University of Wisconsin, has been a general comparative study of all the singular class of rocks known as gabbro occurring in the Lake Superior region. This study has included material already more or less fully described and a much larger amount of wholly new material. The latter is partly from the immense spread of gabbro which overlies the Animiké series on the north side of Lake Superior and partly from other districts, and comprises not only the gabbros which occur in the form of immense sheets or masses, but the closely related and probably contemporaneous gab-

bros which occur in the form of great dikes in the Thunder bay and Pigeon Point region.

Mapping and drafting.—During the winter months Mr. Merriam has drawn six large scale detailed geological maps and one general geological map for the Penokee memoir, besides various sections etc.

Photography.—Mr. Merriam, while on his canoe trips in Minnesota, took 55 views, 8 by 10 inches each, in duplicate, using paper negatives, which he developed on his return to Madison. He has also made during the winter and spring months 200 micro-photographic negatives of thin sections of rocks from the Penokee-Gogebic region. The making of these negatives, in order that satisfactory results should be obtained, has involved a good deal of labor, not only on the part of Mr. Merriam, to whose skill and ingenuity a successful outcome is mainly due, but also on that of myself and of Professor Van Hise, in selecting the sections and in indicating the exact places in them to be photographed.

Publications.—The following papers have appeared during the fiscal year 1886-'87 as results of the work of this division: "The origin of the iron ores and ferruginous schists of the Lake Superior region," by R. D. Irving, published in the American Journal of Science for September, 1886, pp. 256-272, and "Note on the enlargement of hornblende and augites in fragmental and eruptive rocks," by C. R. Van Hise, published in the same journal for May, 1887, pp. 385-388. The former of these papers was prepared in the previous fiscal year, but its publication fell within the present year. During the spring months I devoted much time to the preparation of a somewhat extended paper, entitled "Is there a Huronian group?" which was read in part before the National Academy of Sciences, April 22, 1887, and will be published in the American Journal of Science for September and October, 1887. The object of this paper is the setting forth of the main conclusions to which my studies have led as to the classification of the pre-Cambrian rocks of the Northwest, in particular the conclusion as to the entire separability of a great clastic Huronian series from the older crystalline schists, gneiss, and granite. These conclusions are embodied also in the paper prepared in the spring of 1885 for the Seventh Annual Report of the Survey, on "The classification of the Cambrian and pre-Cambrian formations." The seventh annual report, however, is unpublished at this writing; and, since this paper announces the principles upon which it is proposed to proceed in the final mapping of the Lake Superior region, it has been thought best to embody the conclusions referred to in a shorter paper to be published in advance, and in every way to promote discussion of them before embodying them in the final maps of the Survey. This latter paper also proposes the adoption of an important modification in geological tax-

onomy, viz: the placing of all the pre-Cambrian fragmental groups, including the Huronian, in an entirely new geological system, to be of the rank of the Paleozoic, Mesozoic, and Cenozoic systems, the name Archean being reserved for the pre-Huronian crystalline rocks. Much time has been given by Professor Van Hise and myself to the continuation of our monograph on the Penokee-Gogebic region, a labor which has proved far greater than was anticipated. Dr. Williams has also in an advanced condition his memoir on the "Origin of the schistose greenstones and associated rocks of the Marquette and Menominee regions," to be published as a bulletin of the Survey. The material for several additional bulletins, giving other results of our work, is partly worked up, but it is not thought well to make any announcement of further publications until greater progress is made in their preparation.

All of which is respectfully submitted.

ROLAND D. IRVING,
Geologist in Charge.

Hon. J. W. POWELL,
Director U. S. Geological Survey, Washington, D. C.

REPORT OF PROF. T. C. CHAMBERLIN.

DEPARTMENT OF THE INTERIOR,
U. S. GEOLOGICAL SURVEY,
DIVISION OF GLACIAL GEOLOGY,
Beloit, Wis., July 1, 1887.

SIR: I have the honor to submit the following report of field and office work in the Glacial Division during the fiscal year ending June 30, 1887.

The work of the year has been about equally divided between a continuation of specific lines of investigation previously begun and the inauguration of new ones.

Messrs. Warren Upham, J. E. Todd, Geo. H. Stone, and I. M. Buell have been engaged in the completion or further prosecution of the work they had severally been engaged upon during the previous fiscal year. Messrs. L. C. Wooster, R. D. Salisbury, F. Leverett, and myself have jointly undertaken a work that is measurably new, though a part of the general plan of work previously inaugurated.

In the region about the head of Lake Michigan, and between it and the Erie basin, is a tract that was invaded by successive glacial movements from both these great basins, these movements being more or less inharmonious and conflicting, resulting in exceptionally complicated phenomena. There arose from this a need for detailed study and the development of more refined methods of investigation than those demanded by the simpler drift tracts.

That portion of the tract which lies immediately west and south of the head of Lake Michigan, in Illinois, embracing a complex but rudely concentric belt of marginal moraines, was traced out in detail by Mr. Leverett under my immediate supervision. He traversed on foot essentially every township in the counties of Kane, De Kalb, Du Page, Cook, Will, Kankakee, Kendall, La Salle, Grundy, and Iroquois, besides portions of Vermilion, Ford, Livingston, Putnam, Bureau, Lee, Ogle, Boone, McHenry, and Lake counties. Of this area he made a detailed map of both drift formations and drift topography. He was engaged upon this from the beginning of July to the 25th of November, and again from May 5 to June 25 of the current season. During the winter he prepared and submitted a full report on the region studied, except the portion examined during the last two months.

Prof. R. D. Salisbury undertook the examination of a tract of critical territory outside of and bordering that of Mr. Leverett, and stretching from the elbow of the Illinois river in Bureau county, Ill., to the elbow of the Wabash river in Warren county, Ind. This embraced, in whole or in part, the counties of Bureau, Putnam, Marshall, Livingston, Woodford, McLean, Ford, Champaign, and Vermilion, Ill., and Warren county, Ind. The guiding feature of his study was a broad, low marginal moraine, concentric with the head of the Lake Michigan basin and inclosing the series examined by Mr. Leverett. The border of the loess region, which is approximately but not exactly coincident with this, was also an important feature of his study.

His field work was confined to July and August, except a few days of supplemental revisitation in April last. During the winter he prepared his results in full for publication.

As a third part of the joint work, Prof. L. C. Wooster was engaged during July and August in an examination of the morainal tract between the Kankakee river and Lake Michigan in Indiana, and in the study of an allied tract adjacent to it in St. Joseph, Marshall, Stark, and Pulaski counties, Ind. This area joins at the west that examined by Mr. Leverett and on the south that examined by myself. The peculiar formations of the Kankakee basin were among the subjects of investigation. During the winter he prepared and submitted a report embodying his results.

Besides personally visiting the fields of my associates, I undertook the examination of a contiguous area in northwestern Indiana, embracing, in whole or in part, Newton, Jasper, Pulaski, Marshall, Fulton, Cass, White, Benton, Warren, Tippecanoe, Fountain, Montgomery, Clinton, and Carroll counties. My special endeavor was to trace out the succession of marginal deposits formed by ice movements from the basin of Lake Michigan on the north and from the Erie and Huron basins on the east and northeast, and the

phenomena of superposition that resulted from the encroachment of the one movement upon the ground of the other. The bowlder zones were also special subjects of study.

The results of the four foregoing studies are being collated on a common plan with a view to joint publication.

The opening of the fiscal year found Mr. Warren Upham engaged in the investigation of the Quaternary geology of the basin of the Red River of the North. His especial subject of study was the extinct lake that once occupied that basin, with its deposits, especially its shore lines, which mark both its horizontal and its vertical extension. These lines were accurately mapped and leveled for a large tract in Dakota. Some supplementary observations were made in Minnesota. Mr. Upham prosecuted his work somewhat too vigorously, as it proved, considering the unusual heat and drought of the season, and was overtaken by severe illness near the close of August, which, not yielding to rest and remedies, compelled him to leave the field on the 7th of September. He devoted the autumn and winter to the reduction of his data and the preparation of manuscript. By virtue of a joint arrangement between the Geological Survey of Canada and the U. S. Geological Survey he devoted the latter part of May and the month of June to extending his levelings northward along the ancient beaches in Manitoba.

Prof. J. E. Todd continued, and completed so far as at present contemplated, his studies upon the drift of southern Dakota and the adjoining parts of Nebraska, Iowa, and Minnesota. Its nature has been fully set forth in my previous administrative reports. During the winter he finished and submitted a very fully illustrated manuscript report upon the region indicated, embracing the results of his previous studies.

Prof. Geo. H. Stone continued during July and August the field work upon the glacial gravels of Maine, upon which he had been engaged in previous years and whose nature and purpose have been set forth in my preceding reports. He completed his field studies in August. During the winter he prepared a limited portion of his results for publication.

Mr. I. M. Buell continued during July, August, and early September his study of the bowlder trains of Jefferson, Dane, and Rock counties, Wis., embracing an examination of several associated formations and a mapping of the drift topographies. The nature and purpose of this work have been indicated in my previous reports. He has brought the work approximately to completion. During the winter he remapped on a more satisfactory scale most of his previous results, adding the recently acquired material.

Prof. J. C. Branner in October began an investigation of the relations of the loess and drift and of certain special features of the latter in the Ohio valley, in southeastern Indiana, and in adjacent regions,

but the limited funds available did not permit this to become more than a reconnaissance. It should be remarked that, with a single exception, all the assistant geologists of this division have been engaged in the work of the Survey but a portion of the year and upon the per diem basis. The amount of work they have done has been large relatively to the time actually engaged upon the Survey.

Aside from the field work above indicated my own time has been occupied in executive work, in the revision of material submitted for publication, and in the preparation of manuscript of my own.

Respectfully submitted.

T. C. CHAMBERLIN,
Geologist in Charge.

Hon. J. W. POWELL,
Director U. S. Geological Survey, Washington, D. C.

REPORT OF MR. S. F. EMMONS.

DEPARTMENT OF THE INTERIOR,
U. S. GEOLOGICAL SURVEY,
ROCKY MOUNTAIN DIVISION OF GEOLOGY,
Washington, D. C., July 1, 1887.

SIR: I have the honor to submit the following report of progress in the division under my charge for the year ending June 30, 1887.

Owing to the late date at which the printing of my monograph on Leadville was taken up last year, the final proof corrections and indexing were not completed until near the end of August, too late to inaugurate any extensive field operations that season. In accordance with your instructions, the field work was, therefore, confined to that already in progress in the region around Denver, which was in charge of Mr. George H. Eldridge.

FIELD WORK.

At the date of my last annual report it was thought that the field work in the Denver basin region was very nearly completed; the geology along the foothills (where are the only readily apparent complications of structure and prominent outcrops) had already been finished, and the structure of the plain area not yet studied was supposed to be so simple and regular that a comparatively few weeks would suffice to outline it upon the map. As his work progressed, however, Mr. Eldridge found in the northern part of the area, where several coal mines are already opened, that the beds are broken by a net work of small dislocations, the tracing of which, owing to the paucity of exposures in the plain region, necessitated a most minute and laborious examination, for upon their accurate determination depends the successful exploitation of the coal seams. He

also found that new mines, opened to the east of the Platte river, were working at a much higher horizon than those to the west. He further found that no less than three distinct and unconformable series of Tertiary beds have been deposited in the basin, of which only scattered relics, resting unconformably on the Laramie or coal bearing rocks, still remain. It was only after protracted search that sufficient vertebrate remains were collected to afford a means of determining the age of these different deposits. The study of these new elements of interest in the region protracted the field work until the commencement of the year 1887, and it was not until March that Mr. Eldridge felt assured that he had gathered all the information necessary for the preparation of the geological map of the region. Upon this work he has been diligently engaged ever since, but, owing to the great number of instrumental determinations of outcrops rendered necessary by the peculiar conditions, it will probably take some months yet to bring the map to such a stage of completion that the final deductions can be drawn from it. A great portion of the monograph is, however, already written, and I trust that in the autumn we may be able to push it rapidly to publication.

As, owing to reasons given above, I was unable to leave Washington until the end of August, my own field work was confined to short visits to different mining districts for purposes of comparative study of varied conditions of ore deposition.

In September, accompanied by Mr. Eldridge, I visited Leadville, the Ten-Mile district, and the mining region on Eagle river, in the vicinity of Red Cliff. Later, accompanied by Mr. Whitman Cross, I traversed the San Juan mining region from Durango to Ouray. In October, on my way to the East, I visited Butte, Mont., and spent a week in a reconnaissance examination of the remarkable deposits of this important mining district, which now ranks with Leadville in value of mineral product. Such preliminary studies, although not affording sufficiently accurate or complete data for reports upon the individual districts, enable us to make comparisons and generalizations which add greatly to the value of monographs already undertaken.

LABORATORY AND LITHOLOGICAL WORK.

In the laboratory at Denver Mr. L. G. Eakins during the year has made about forty complete analyses of rocks and minerals, many of the latter very rare and hitherto unknown in this country, and some possibly new to science. In addition to this, he has made over fifty analyses of coals from the Denver basin and many qualitative tests and assays of ores and vein materials.

In addition to his labors upon the material gathered to illustrate the various monographs in progress, Mr. Whitman Cross, who has charge of this branch of the work, has made many important investigations upon material collected on the short trips mentioned above,

and also upon that brought to the Denver office by members of the Colorado Scientific Society and others interested in the geological development of the Rocky Mountains. By this means our knowledge of the eruptive geology of this region has been very materially increased, and a number of rock varieties hitherto not known to exist there have been discovered.

OFFICE WORK.

The office work during the year has been mainly devoted to the preparation of the reports upon the Ten-Mile and Silver Cliff districts, which it has been decided to publish in a single volume, and of that upon the Denver basin region. Both of them are in an advanced state of preparation, but for various reasons it is not possible to foresee exactly at what time they will be ready for publication. Work upon the area of 30 miles square in the Gunnison region, the survey of which is already more than half completed, has, under your instructions, been temporarily suspended until the other monographs mentioned above shall have been published.

Very respectfully, your obedient servant,

S. F. Emmons,
Geologist in Charge.

Hon. J. W. Powell,
Director U. S. Geological Survey, Washington, D. C.

REPORT OF DR. A. C. PEALE.

Department of the Interior,
U. S. Geological Survey,
Montana Division of Geology,
Washington, D. C., July 1, 1887.

Sir: I have the honor to submit the following report of operations of the Montana division for the year ended June 30, 1887:

FIELD WORK.

The field party was organized at Bozeman under the direction of Dr. F. V. Hayden on the 18th of August, 1886, and work was continued until the 20th of September. The collections of the previous year contained specimens of eruptive rocks which, upon preliminary examination by Mr. George P. Merrill at the National Museum, were found to be of considerable interest, and it was decided that Mr. Merrill should join the division for the purpose of studying the field relations of the rocks he had examined in the laboratory.

The first portion of the season was devoted to the re-examination of the localities near Ft. Ellis. The outcrops, which are very obscure, occur in the low hills lying to the northeast of the fort.

They are apparently distinct from one another, and are found in Laramie (?) sandstones a short distance east of the line of juncture with the lake beds, and extend northward, the first rocks described coming from the most southern outcrop. The following are Mr. Merrill's preliminary notes on these rocks:

The eruptive rocks of the region covered by this report are full of interest, but present great difficulties in the way of satisfactory study, owing to obscure outcrops and consequent weathered condition of specimens obtained.

The main varieties are enumerated below:

I. *Hills northeast of Ft. Ellis.*—(1) Quite typical hornblende andesite, interesting chiefly on account of its large, reddish, pleochroic apatites. (2) Augite andesite, much decomposed and amygdaloidal; amygdules filled with analcite. (3) A dark greenish peridotitic-appearing rock, highly altered and showing under the microscope abundant large perfect crystals of a green pyroxene, clear colorless olivines, and iron ores embedded in a wholly crystalline ground mass now largely zoisite (?). Indications point to a somewhat anomalous variety of basalt; but less altered material must be obtained before anything more definite can be said. (4) A very compact highly silicious rock varying in color from nearly white through light yellow and pink to dark gray and even greenish, and with only small scales of black mica and crystals of plagioclase macroscopically developed. The thin section shows the structure to vary from felsitic, toward the center of the sheet, to glassy or only partially devitrified, nearer the contact. Adopting the Rosenbusch system of classification, I should place it under the quartz porphyries, varieties *felsophyr* and *vitrophyr*. In structure it is almost identical with the well known felsophyr of Elfdahlen, Sweden.

The rock last described (4) is from 20 to 25 feet in thickness and has been traced a distance of at least 26 miles from Rocky cañon northward along the eastern side of the Bridger range. Wherever examined, the edges on both sides have been found very much decomposed. The first three rocks described outcrop within a space of less than one mile.

Later in the season two other igneous rocks were examined in the northwestern part of the Gallatin valley. The first of these occurs in connection with faults in the Potsdam sandstone, about three or four miles northeast of the junction of the East Gallatin and the West Gallatin rivers. The second occurs about four miles northwest of the same point on Cottonwood creek. These rocks are described by Mr. Merrill as follows:

II. *Hills northeast of East Gallatin river.*—Mica-trachyte: This rock occurs as an intrusive sheet between strata of Potsdam age. Structurally it is wholly crystalline and is otherwise of interest from the constant interpenetration of its sanidines with plagioclase crystals. Black mica alone is the characterizing accessory, it being accompanied by neither hornblende nor augite.

III.—*Cottonwood creek, east of Gallatin river.*—The eruptive here occurs as an immense sheet intruded in Upper Jurassic or Lower Cretaceous strata and has been exposed only by the breaking through of the overlying rock and subsequent erosion by the waters of Cottonwood creek. The essential constituents as shown by the microscope are augite, a plagioclase feldspar, and iron oxides; to this list may be added scattering flakes of secondary black mica and apatite needles. The compo-

sition is therefore that of a diabase or basalt, but it is of an unusual type in that the augites possess in most cases very perfect crystal outlines and are of all sizes up to nearly a centimeter in length, in place of the usual extremely irregular and interrupted forms. In this respect the rock resembles an augite-porphyrite, though the amount of amorphous or felsitic base is very small and difficult to detect, owing to decomposition products.

In addition to the work just indicated the westward extension of the lake beds as far as the Madison valley was traced and a considerable portion of the short field season was devoted to their examination in the area between the Gallatin and Madison rivers. They were found to be composed in large part of volcanic glass or pumiceous dust, as in the Gallatin valley.

A few vertebrate remains were found in the bluffs overlooking the Madison valley and a large collection of fine wood opal was obtained from the same locality. Another interesting point in connection with the lake beds of this area is the occurrence of old hot spring deposits in strata lying at a considerable distance below the beds that now form the general surface. They are well shown in several gullies that have been cut down into the plateau which slopes from the Madison bluffs eastward toward the West Gallatin river.

After disbanding the field party, Mr. Merrill and myself visited one of the old lake basins on the Sweetwater river, a tributary of the Jefferson, and secured specimens for comparison with the lake deposits of the Gallatin valley.

Mr. Merrill then left me and went to Nebraska to visit similar occurrences in the southern portion of that State.

OFFICE WORK.

The office work during the year consisted mainly of the study of the field notes and the continuation of work on the subject of mineral springs. A third paper on the statistics of the mineral waters of the United States was prepared for publication in Mineral Resources of the United States, 1886.

Bulletin No. 32, prepared during the latter part of the preceding fiscal year, was published and a large number of copies have been distributed. A paper on the "Classification of American mineral waters" was prepared and, with your permission, read before the American Climatological Society in Baltimore, June 1.

On account of continued illness Dr. Hayden resigned December 31, 1886.

Very respectfully,

A. C. PEALE,
Geologist in Charge.

Hon. J. W. POWELL,
Director U. S. Geölogical Survey, Washington, D. C.

REPORT OF MR. ARNOLD HAGUE.

DEPARTMENT OF THE INTERIOR,
U. S. GEOLOGICAL SURVEY,
YELLOWSTONE NATIONAL PARK DIVISION OF GEOLOGY,
Washington, D. C., July 1, 1887.

SIR: I have the honor to submit herewith the following report of operations conducted under my supervision during the year ended June 30, 1887:

FIELD WORK.

Field work during the year has been confined to the Yellowstone Park and the adjacent country, the area covered by the survey being determined in part by the geological problems presented and in part by the boundaries of the reservation as they were laid down in the bill before Congress at its last session for the enlargement and maintenance of the park; indeed, the geological problems presented and the proposed geographical boundaries cover nearly the same area.

On June 30, 1886, accompanied by Mr. Thomas J. Ryder, I reached Bozeman, Mont., and immediately began the necessary preparations for a summer's field work in the Yellowstone Park. Camp was made July 7, and after many unavoidable delays the party left Bozeman for the Mammoth Hot Springs on July 13, arriving at the Park after a three days' march. Remaining at the springs only a few days I proceeded to the Upper Geyser basin, where I established the first permanent camp for the season, July 22, on the ground occupied by the party in former years while carrying on investigations of the geysers and hot springs of this region.

The corps of assistants in the field the last season was an able one and included several who were members of the organization in previous years and men of much experience in field work. The party consisted of the following aids: In physics, Dr. William Hallock; in geology, Mr. Joseph P. Iddings and Mr. Walter H. Weed, of the regular corps, and Mr. Samuel L. Penfield, of the Sheffield Scientific School, who rendered most efficient service as volunteer assistant in geology for nearly two months during the college vacation. Mr. Ryder acted as disbursing clerk and secretary.

General geological survey work was mainly confined to the southwestern portion of the park and the narrow strip of country lying between the southern boundary and the forty-fourth parallel of north latitude. This embraced the Pitchstone plateau and the southern end of the rhyolite body which forms the elevated rock mass of the plateau of the park. By extension southward to the forty-fourth parallel the survey takes in the northern spurs of the Teton mountains and the Wind River range, thus enabling the geologist to bring out the structural relations of these older ranges with the later rhyolite body.

On July 23 Mr. Iddings, accompanied by Mr. Penfield, left for the southwestern portion of the reservation for the purpose of examining the rhyolite flows to the westward beyond the boundary of the park into Idaho. He returned on August 3, leaving again on August 7, his party being re-enforced by Mr. Weed. I left the Upper Geyser basin July 26 for the exploration of the Pitchstone plateau and the southern end of the Madison plateau, returning to main camp August 9. On August 11 I again started southward from the Upper Geyser basin, following down Lewis river to its junction with the Snake river, spending some time in the examination of the Wind River range. On this trip I was accompanied by Hon. Charles H. Allen, member of the House of Representatives from Massachusetts, who joined me for the purpose of examining the park as a forest reservation, studying its importance to the Government from an economic standpoint. I met Mr. Iddings and his party on Snake river, and the greater part of the summer was occupied in field work in this region. The Teton mountains are mainly made up of an Archean mass, the northern spurs on the west side of the valley being overlaid by Paleozoic rocks, and the Wind River range is for the most part composed of Mesozoic strata. This part of the survey is now nearly completed, and there only remains on the east side the southern end of the Absaroka range and the southeastern portion of the country covered by the Yellowstone map.

Mr. W. Hallett Phillips, who was with me the previous year, again made his headquarters while in the park at my camp. He came out in July, having been reappointed by the Secretary of the Interior as special agent to report to the Department upon the condition of the National Park and to suggest what changes, if any, were needed to secure more efficient management. Mr. Phillips remained with me during the greater part of the summer, and I was enabled to aid him in many ways in the prosecution of his work.

The annual detailed examination of the hot springs and geysers was carried on as usual in a very satisfactory manner by Mr. Weed, who during the summer visited most of the areas of thermal activity. Changes are steadily taking place in the deposition of sediments and overflow of waters, usually with extreme slowness. From a geological point of view, however, they are exceedingly interesting and significant. There is, however, but little to warrant the many assertions as to great and sudden changes which the park is undergoing in the geyser regions. I may repeat here, what I have taken occasion to say in a former administrative report, that I see no diminution in the intensity of action or in the amount of discharge from the springs and geysers since they have been subjected to careful observation.

During the year there have occurred a number of local earthquake shocks which, according to personal statements, have been felt ten

or twelve miles from the probable seat of action. They were doubtless caused by the explosion of steam in the geyser basins and probably originated not far below the surface. That such explosions occur with more or less frequency there is good reason to believe, but I see but slight evidences of violent earthquake action within very recent times.

Dr. Hallock completed his investigations upon the physics of geyser action, the depths of the reservoirs, and the changes in temperature before and after eruption. The repeating of his observations through a series of years and the confirming of previous experiments add greatly to the value of the results obtained. In addition to his other duties Dr. Hallock undertook to gauge the amount of water discharged from the lakes, springs, and rivers of the park through the two larger rivers, the Yellowstone and the Snake. In the prosecution of this work he employed a Nettleton meter, which seemed to him best adapted to yield accurate results and which has given satisfaction in Colorado in gauging the water supply for purposes of irrigation. The peculiar topographical structure of the park plateau, which serves as a natural reservoir for the Yellowstone and Snake rivers, and the unique climate, with the great precipitation of snow, render the water supply of the region a question of great economic importance to all interested in the future of the Columbia and Missouri rivers.

Geological work was abruptly terminated by heavy snows. On the evening of October 9 a storm began and continued without abatement for thirty-six hours, the snowfall measuring 26 inches. With some difficulty I reached the Mammoth Hot Springs. The weather continuing unpleasant and more or less threatening, I decided to break camp for the season, although with regret, as there were still unsettled questions which required some additional work. After packing the collections of rocks, fossils, sediments, and samples of water and gases, I left the park October 17, proceeding to Bozeman, where the party disbanded. I reached Washington November 1. Early in the month all the assistants engaged in office work reported for duty.

The collection of Tertiary plant remains has received large additions from several localities and many beautiful and valuable specimens have been obtained during the year. These, together with the accurate geological sections relating the different plant beds to one another, must throw considerable new light upon one of the most important geological questions in this region and one which has occupied much of my time and thought, viz, the duration of the volcanic period. Did it continue throughout the greater part of the Tertiary period? Does the flora indicate periods of long rest? Does it indicate marked differences of climate?

In connection with his other duties Mr. Iddings, as in previous years, added largely to the stock of photographic negatives of geological subjects which might be needed for purposes of illustration. As aids to field notes they are invaluable.

OFFICE WORK.

During the winter the engraved map of the Yellowstone Park region in four atlas sheets was received from the geographical division. It is a finely executed map, highly creditable to both surveyors and engravers, and will be fully appreciated by the thousands of tourists who already annually visit the national reservation. In consultation with Mr. Henry Gannett, geologist in charge of geography, it was agreed that the necessary new names to designate the unnamed mountains, valleys, and streams should be mainly selected from the beasts, birds, fishes, trees, flowers, and minerals found within the park or the adjacent country. Other than the names bestowed in honor of the early explorers of this region, but few personal names have been placed upon the grander physical features. The most important name given is that in honor of the present Secretary of the Interior, who has shown great interest in the preservation and maintenance of the Yellowstone Park. Lamar river takes the place of the crude name East Fork of the Yellowstone. Coulter peak designates one of the grandest summits in the Absaroka range and perpetuates the name of the first white man of whom we have any record who penetrated this rough and rugged country.

The analytical chemical work upon the thermal waters of the park which engaged the attention of Messrs. Gooch and Whitfield for a long time in the chemical laboratory of the Geological Survey and which was nearly completed a year ago has since been arranged for final publication. When published it will make a most valuable addition to the bulletins of the Survey.

From a geological standpoint I have been greatly interested in the composition of these waters. All the geyser waters in the park carry arsenic in solution ; indeed, they are so rich in sodium arseniate as to be very properly classed as arsenical waters, and as such may some day take high rank for their remedial and alterative properties. While they carry less arsenic than the thermal springs of La Bourboule in the Auvergne, famous for their curative properties, the enormous output may more than compensate for differences in the strength of the waters.

For a long time I have had under investigation the brilliant mineral green coatings found deposited upon the silicious sinter around several hot spring pools and geyser vents. Analyses show this coating to be the comparatively rare mineral scorodite, a hydrous arseniate of iron. So far as I know the deposition of scorodite from arsenical waters has never before been noticed.

During the winter and spring, in addition to the preparation of the results of field work, considerable time was occupied in investigating certain problems in the petrography of crystalline rocks.

Very respectfully, your obedient servant,

ARNOLD HAGUE,
Geologist in Charge.

Hon. J. W. POWELL,
Director U. S. Geological Survey, Washington, D. C.

REPORT OF MR. GEORGE F. BECKER.

DEPARTMENT OF THE INTERIOR,
U. S. GEOLOGICAL SURVEY,
CALIFORNIA DIVISION OF GEOLOGY,
Washington, D. C., July 1, 1887.

SIR: At the date of my last annual report my monograph on the geology of the quicksilver deposits of the Pacific slope seemed close to completion, only some chemical questions still remaining unsettled. Such inquiries, however, can seldom be answered promptly, and their solution has occupied a large part of the year which has elapsed. All the most important portions of the work, however, were finished in February last. In the same month I printed a digest of my results on the natural solutions of cinnabar, gold, and the associated sulphides,[1] in which it was shown that the metals form sodium sulpho-salts, soluble in water, and that such salts actually exist in the waters of Steamboat Springs.

In March I proceeded to Europe, under your orders, for the purpose of examining the Almaden mine of Spain and the Italian quicksilver mines and of instituting comparisons between them and the Californian ore deposits. Thanks to the cordial feeling which seems to exist towards the U. S. Geological Survey among all European geologists, I was received with the greatest courtesy and was given every possible opportunity of accomplishing the objects of my mission. The published descriptions of the Almaden mine left it doubtful whether the results which I had obtained in California were applicable in Spain or not. Careful study of the locality, however, shows that Almaden from a geological point of view is not dissimilar to many quicksilver localities in California, though no such vast, rich, and regular deposit of cinnabar is known to exist in the United States or elsewhere in the world. The mines of southern Tuscany also tend to confirm in the strongest manner many of the conclusions drawn from the deposits of the United States. While in Italy, I also took occasion to compare and contrast the famous serpentines of Tuscany with those of California. There are very marked and impor-

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[1] Am. Jour. Sci., third series, vol. 33, 1887, p. 199.

tant differences in the two regions. A small part of the information derived from this excursion will be embodied in Monograph XIII, but the greater portion will be published separately when the necessary laboratory work has been finished.

The monograph on the deposits of the Pacific slope will be ready for the printer during this month and a summary of the results appears in this volume.

Early in the last fiscal year I published a paper entitled The Washoe Rocks,[1] in which were embodied the results of studies on the diorites, diabases, and Tertiary volcanics of Virginia City and Steamboat Springs, referred to in my last annual report. These observations supplement and confirm the conclusions drawn in my monograph on the geology of the Comstock lode. At a later date I published an essay on the texture of massive rocks, in which it was pointed out that the relation between granular rocks and porphyritic masses is of a very different character from that which exists between glassy rocks and holocrystalline, porphyritic ones. Granular structure is a result of the simultaneous crystallization of various minerals. Granting that a given homogeneous, eruptive magma may be cooled so slowly as to yield a porphyritic, holocrystalline product, it does not seem to follow, either theoretically or from unambiguous observations, that in the same magma, still more slowly cooled, the various ultimate compounds would crystallize simultaneously or even tend to do so. The granular rocks seem rather to have resulted from the solidification of imperfectly fluid magmas, or pastes, in which the chemical composition varied from point to point, and the granular rocks seem never to have been so intensely heated as porphyritic or glassy masses of the same average composition.

Mr. Waldemar Lindgren has published an interesting sketch of the Calico district, San Bernardino county, Cal.[2] Scarcely anything had previously been known of the geology of this important mining region. The ore deposits occur chiefly in rhyolite, and form veins and stock works or occupy the interstices of crushed zones of the lava. The ore consists of decomposition products of silver and copper sulphides, and barite and jasper are the gangue minerals.

One of the greatest geological problems which the country presents is that of the gold belt of California. Not only are the ore deposits of this region of vast economic importance and of the highest scientific interest, but they cannot be discussed satisfactorily without including in the subjects of inquiry the history and structure of the great Sierra Nevada. When you intrusted me with the investigation of this subject it appeared to me essential to include in it a

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[1] Bull. 6 Cal. Acad. Sci., 1886, p. 93.

[2] Trans. Am. Inst. Mining Engineers, February, 1887. The field work for this paper was done by Mr. Lindgren at his own expense during a leave of absence.

much larger area than that characterized by numerous gold deposits, and indeed to embrace the entire western slope of the Sierra, from Mariposa to the Feather river, an area of about 12,000 square miles. At my request a topographical map of this region on a scale of one inch to the mile is being prepared, and two entire field seasons have already been devoted to it. In undertaking the geological examination of so large an area the plan adopted is of great importance. As the work progresses, it is as nearly as possible certain that many hitherto unsuspected facts and relations will be discovered which will prove to have an important bearing upon the entire region; consequently, if one were to attempt to finish the investigation of each portion of the area on the occasion of a first visit, much of the early work would need to be reviewed, if not repeated, before the completion of the whole. On the other hand approximate geological work is scarcely better than none. Fortunately a third method of conducting the inquiry suggested itself, to which as yet I have found no objection. This consists in beginning by a preliminary survey of the region, in the course of which only the simplest features of the geology will be mapped, viz, the granites, the metamorphic series as a whole, the gravels, the volcanic rocks without subdivision, and the later metamorphosed strata. While only these features will be mapped during the preliminary survey, extended notes on all occurrences will be preserved, and at the completion of this work we shall have an accurate and valuable, though an incomplete, geological map; we shall also accumulate a body of information which will enable us to select the most appropriate localities for the study of the structure of the range, the age of the gravels, the glacial phenomena, the subdivisions of the metamorphic area, the character and the date of the metamorphism, the relations of the eruptive rocks, the genesis of ore, etc.

Messrs. Turner and Lindgren were engaged throughout the last season and during the past spring on this preliminary survey, with encouraging results. About three thousand square miles are already mapped, and important discoveries have been made, such as that of Paleozoic fossils in hitherto unknown localities. I shall join them in this work next year. We shall follow hard upon the heels of the topographers and a few months after the topographical survey is complete the preliminary geological map will be transmitted to you.

Very respectfully, your obedient servant,

G. F. BECKER,
Geologist in Charge.

Hon. J. W. POWELL,
Director U. S. Geological Survey, Washington, D. C.

REPORT OF CAPT. C. E. DUTTON.

DEPARTMENT OF THE INTERIOR,
U. S. GEOLOGICAL SURVEY,
DIVISION OF VOLCANIC GEOLOGY,
Washington, July 1, 1887

SIR: Herewith I have the honor to submit my report of the operations of the division under my charge during the fiscal year ending June 30, 1887.

FIELD WORK.

My report for the last fiscal year covered operations in the southern part of the Cascade range, in California, and as far northward as Ashland, Oreg., which is situated twelve or fifteen miles north of the California boundary. On the 1st of July I was camped with my party in Ashland and engaged in making preparations for a somewhat thorough examination of Crater lake. This remarkable lake is situated upon the axis of the Cascade range, about sixty-five miles north of the California boundary and near the intersection of the forty-third parallel and the one hundred and twenty-second meridian. So striking are its physical and geological features that it was deemed well worthy of a special examination. The difficulties to be overcome, though not extremely great in themselves, were of an unusual kind. The lake occupies a profound depression in the Cascade platform and is girt about by lofty walls which descend at once into deep water. Boats are absolutely necessary for traveling about within its basin. Accordingly I had arranged for the construction of a good boat which could be used for sounding and also for two small skiffs for auxiliary purposes. A simple sounding apparatus had also been devised and fitted to the large boat. Tackle for lowering the boats into the water from the cliffs above was also provided. One other requisite was a number of stalwart men, who could lower the boats, row them, and do the hard labor connected with the examination of the lake. For the latter purpose I wrote to General Gibbon, commanding the military department of the Columbia, requesting that ten enlisted men be placed at my disposal. He at once detailed them from the troops at Vancouver barracks, and, placing them in command of Capt. Geo. W. Davis, Fourteenth Infantry, directed the party to proceed to Ashland, to act as an escort and to render whatever assistance might be necessary. Captain Davis arrived with the men at Ashland on July 4.

The large boat was mounted upon the running gear of a wagon upon which a framework had been built in such a manner that the boat could be suspended in slings and bear a journey of a hundred miles over rough mountain roads without injury from shocks or strains. The small boats were mounted upon wagon gears in a sim-

pler manner. On the 7th of July the party left Ashland and proceeded northward, crossed the Rogue river, and turning eastward soon began the ascent of the valley of that river. A journey of four days brought us near the locality. Within a mile of the Cascade divide it was necessary to leave the road and ascend the mountain or truncated cone in the summit of which is the lake basin. With great labor the wagons were hauled up the incline over snow banks and through the forest until they rested upon the brink of the cliff which looks down into the lake. Preparations for lowering the boats were at once begun. Captain Davis took charge of this work and accomplished it with perfect success.

The cliff here is about nine hundred and fifty feet above the water surface and is broken down into a slope of about 40°, with numerous small ledges. A cradle was made of scantlings, to which the boat was lashed, and the tackle, made fast to trees, was used to hold back the boat, while the men urged it forward and downward over the great snow banks, talus, and ledges. The process was not without peril. Apart from the danger of working upon so steep a slope, the melting snow frequently detached large stones, which went crashing down, threatening the men and boat alike. The task, however, was accomplished without accident, though there were numerous narrow escapes. The lowering of the small boats was a much easier matter. Next followed the work of cutting a trail from the summit to the water, in order to reduce the severe labor of ascending and descending the cliff. To camp below was impossible; there was no room to lie down in a position approaching horizontality.

The sounding apparatus was then set up in the large boat and a series of soundings was begun. At the first experimental cast, a few hundred feet from shore, a depth of 1,480 feet was reached. Although the depth was believed to be great, this result exceeded the anticipations. A series of soundings was begun and pushed forward with as much diligence as possible. In all 168 soundings were made, distributed over the area of the entire lake as uniformly as practicable. The position of the boat at each cast was determined by two plane tables planted upon the walls above. The general results of the soundings may be summarized as follows:

The inferred configuration of the bottom may be conceived of as a nearly plane surface for the most part, upon which stand three abruptly rising prominences. The largest of these rises above the surface of the water and discloses itself as a large cinder cone. This one stands near the western margin of the lake. Several streams of lava project from the base of the cone and are seen above the water between the cone and the nearest part of the lake wall. The height of the cone above the water is about 650 feet. The other two prominences are disclosed only by the plummet, for their tops are submerged, one at a depth of about 450 feet, the other at a depth of about

825 feet. The depth of the floor upon which these prominences stand varies from 1,600 to 2,000 feet. At the deepest cast the wire gave a reading of 1,996. To this should be added a small but unknown correction for the stretching of the wire, which will make the true depth of this cast fully 2,000 feet. So far as known to me this is the deepest fresh water in the United States.

Had time permitted an effort would have been made to ascertain with greater precision the shape of the submerged prominences; but it would have required the whole available time remaining to accomplish it, and this work can be resumed later if opportunity should offer.

Before leaving Ashland arrangement had been made with Mr. M. B. Kerr, topographer, and his assistant, Mr. Eugene Ricksecker, to meet me at the lake in the latter part of July for the purpose of making a good map of the lake and of the country immediately surrounding it. As the progress of the triangulation required that both of them should make a primary station upon Mt. Scott, in the immediate vicinity, this arrangement in no wise interfered with their plan of work. They arrived duly, and in the course of a week they obtained the data for making a map, which has since been drawn by Mr. Kerr. The dimensions of the lake prove to be 6¼ miles in length and 4½ miles in width. Its shape is nearly elliptic, with only a few moderately well marked bays.

While the soundings progressed a study of the surroundings of the lake was made by myself upon the platform above and around the inner walls by boat below. The lake has no visible outlet. Its watershed is limited to the area within the sharp crestline of the cliff which incloses it. From this crestline, in directions away from the lake, the profile of the country descends at every point of its periphery with a rapid slope. In a word, the basin is the heart of a great volcanic cone, truncated far down toward its base, so that only the basal portions of the volcanic pile remain. The origin of this great depression is I think capable of explanation by processes which have their counterparts and illustrations in other volcanic countries and without the necessity of appealing to any action which is not abundantly exemplified elsewhere. Without going into details here, and reserving for future discussion an explanation and synthesis of the related facts, I will confine myself to saying that the evidence is satisfactory to the effect that this depression was formed in the same manner as the great calderas at Kilauea, Mauna Loa, and Haleakala, in the Hawaiian islands; the Volcan de Taal, in the Philippines; the great cirque of Teneriffe; and the large calderas of Central America. It possesses no feature which is not to be found in some one or more of those striking formations, and its most characteristic features are to be found in all the others.

My work at Crater lake was completed on the 5th of August, and on that day I started upon the return journey down the Rogue River valley to Medford, on the Oregon and California railroad. Here the wagons were turned into depot and preparations were speedily made for taking the field with a pack train. I had contemplated a long journey northward, crossing and recrossing the Cascade range wherever practicable and advantageous, for the purpose of obtaining knowledge of the geological features presented on its western flank and in its axial portions. I designed prosecuting the journey in this way until the Columbia river was reached. Leaving Medford on the 11th of August, I followed down the left side of the Rogue River valley as far as Gold Hill.

My previous observations on the route from the Klamath river northward as far as Medford had indicated the general structure of the western flank of the Cascade system up to that point. Along this line the late Cretaceous and early Tertiary beds, consisting of sandstones, shales, and fine stratified tuffs, with interbedded conglomerates and lavas, are seen to turn upward toward the west, while their edges are inferred to be similarly turned up beneath the alluvium of the Rogue River valley and to lie against the metamorphic masses which constitute the Coast range in southern Oregon. Immediately north of the Rogue river, however, these strata have a diminished dip to the eastward and their margins trend northwestward and even westward. It begins to be apparent now that this part of the Coast range, during later Mesozoic and early Cenozoic times, was a large island, and in the vicinity of the Rogue river its ancient coast line swings to the westward, as if gradually turning around its northern end. The stratified beds of the Cascade system meantime reach farther and farther westward, until near the mouth of the Rogue river they at last extend to the Pacific shore. My first plan of following this ancient shore line was therefore seen to be inconsistent with the project of studying the Cascades, as it would have carried me to the westward among sedimentary formations.

Leaving the Rogue River valley at Grant's pass, I pursued the road to the northward. The country passed through is one offering singular obstacles to the study of geology. It is rugged in the extreme, being a maze of deep, V shaped gorges separated by knife edges clothed with the gigantic forest trees peculiar to the region. In spite of the steepness of every gorge and hillside, the trees, chapparal, and undergrowth are so effective in holding the soil firmly to the hillsides that it is hard to find a rock exposure or even a stone big enough to throw at a bird, except in the beds of the running streams. We are left to infer as best we may the stratigraphy of the country from the very few exposures of rocks, from the nature of the soil exposed by the cuts of the roadway, from pebbles in the streams and washes, and from the topographic features of the country. These

at best serve only to tell us whether the country rock is volcanic, metamorphic, or sedimentary, and that only at a few points here and there. They give no clew to the ages and the relations of the inferred rock masses. This is one of those districts where the geologist must work out his map on his hands and knees. All that could be gleaned was that the road passed through tracts which changed frequently from sedimentary to metamorphic and volcanic. The volcanic rocks, however — and these were generally the best exposed — were mostly of ancient types, the most abundant of all being those forms of peridotite which are displayed in enormous masses and with a wide distribution throughout the contorted Paleozoic or older slates and metamorphics of northern California and southern Oregon.

The geological relations here are worth dwelling upon for a moment. This part of Oregon during the later Mesozoic and early Cenozoic was probably an archipelago. To the eastward stretched a mediterranean whose farther shore was the great island which in those ages occupied the area that is now the great basin of Nevada, eastern Oregon, and southern (perhaps also northern) Idaho. The straits and passes between the islands which were scattered throughout this old mediterranean were loaded with sediments, large remnants of which still remain, though a great portion of them has been removed again by the erosion of subsequent periods. This state of affairs is plainly disclosed north and south of Shasta and in Shasta valley, and is revealed with remarkable clearness in the middle courses of the Klamath valley and upon the northern flanks of the Siskiyou. Many portions of the Rogue River valley disclose it. To the eastward the traces of this earlier history are buried beneath the enormous masses of lavas and conglomerates which constitute the Cascade platform, but in the great gorges excavated in its western flank we still find many proofs of the same general fact.

Whatever observations could be made in a country so obscure as that which lies between the Rogue river and the South Umpqua betokened the same order and system of facts as that described. The route led from metamorphic country rocks to sedimentaries, and vice versa, the sediments becoming more frequent and extensive and the metamorphics fewer. The fossils obtained were either of the Chico group or Miocene, sometimes one, sometimes the other. None of Eocene age were found, nor were any of Miocene age collected until we approached the vicinity of the upper Willamette valley, though I believe that other observers have found them in some portions of the valley of the Umpqua.

Reaching Eugene City, I spent a few days in examining the head of the Willamette valley. It is a Miocene basin, with abundant characteristic fossils. A feebly pronounced watershed or divide separates it on the westward from a region draining more directly into the Pacific and covered with strata mostly of the same age.

Leaving Eugene City I ascended the valley of the McKenzie fork to cross the mountains again. This valley is cut deeply into the range, and, though the heights on either hand are massive lavas, there is a considerable stretch of the valley in which the metamorphics are again laid bare. These rocks are also disclosed over a considerable area and are margined on the west by the Miocene and Cretaceous and on the east by overlying lavas. The area in which these rocks are disclosed was probably one of the islands of the old archipelago.

As we ascend the McKenzie fork traces of glaciation at length appear, and as the Three Sisters come into view the traces become indicative of glaciation upon a much grander scale than any observed to the southward. In the southern Cascades the relics of the glacial period indicate glaciers, often of large size, upon the peaks and larger mountains, but seldom anything more; but as we began, at an elevation of about sixteen hundred feet, the ascent of the main ridge of the Cascades in the McKenzie drainage it speedily became apparent that these phenomena were of a different order. In these latitudes the whole summit platform of the Cascades has been powerfully glaciated by a continuous ice sheet covering the entire summit and flowing away to the westward, down into the great gorges which lead into the Willamette valley. It would be difficult to find anywhere relics of the glacial period more eloquent or more characteristic. Their freshness is remarkable. Above an altitude of four thousand feet they are omnipresent, except where they are overflowed with lavas which are younger still. The great gorge which leads from the McKenzie up to the bases of the Three Sisters is a magnificent example of a glaciated gorge whose appearance could not fail to strike the crudest observer as much by the peculiar features which the ice has sculptured upon its precipices as by the magnificence of the scenery to which they give rise. Upon the Middle Sister there is now a large glacier descending from the upper amphitheaters of the mountain at an altitude of about six thousand feet. It has a length of over four miles and a width of nearly three-fourths of a mile and exhibits fine lateral and terminal moraines.

The volcanic rocks in this portion of the Cascades were found to differ much from those farther southward. In the southern Cascades the dominant type of rock is a true andesite, generally bearing hypersthene and less frequently hornblende or augite; many basalts are found, but they show little olivine or augite and approach the andesites in composition; rhyolitic rocks are very uncommon. But in the vicinity of the Three Sisters the basalts, which are very numerous, are of a more basic type; rhyolites and dacites are abundant, and indeed the two varieties shade into each other. The older rocks, however, are still andesitic. The andesite almost everywhere appears to form the main bulk of the Cascade platform. The rhyolites and the dacites are younger and form some of the dominant

mountain piles which stud the platform, while youngest of all are the heavy basic basalts. The middle and highest peak of the Sisters has been in action since the close of the glacial period and its upper cone has been remodeled and reconstructed at a comparatively recent epoch. Some of the younger flows are rhyolite or dacite, for here the two types approach each other so closely that a distinction is difficult. There are large masses of obsidian, many of which present those spherulitic concretions which are so characteristic of the acid lavas of Yellowstone Park. In many places the same lava shows a curious admixture of the highly glassy with the lithoid form, and the two are intermingled in thin, contorted bands, from a few millimeters to a few inches in thickness, and thoroughly kneaded together.

Perhaps the most impressive features of the lithology are vast fields of young basalt. These are postglacial, and indeed are in some cases probably but a few hundred years old. There are some grand expanses of these basalts immediately north of the Sisters. One of them covers an area which was estimated to exceed one hundred square miles. This lava is so recent that no vegetation has as yet taken root upon it and it presents a scene of blackness and roughness fully equal to anything I saw in the Hawaiian Islands. The greater portion of it emanated from a vent seven or eight miles north of the Sisters, which is now conspicuously marked by a broad, flat lava cone. A good many copious outpours have issued from it, for it is plainly seen that some of the lava sheets are older than others, though all are postglacial. There are also several broad streams of similar scoriaceous basalt which have flowed from parasitic vents on the northern flank of the north Sister and have become interbedded with those just referred to. Farther northward, around Jefferson and at intervening places, are found many great and recent basaltic eruptions.

There are few localities equal in geological interest to the neighborhood of the Three Sisters. The glacial phenomena are exceptionally well defined, and there is a large existing glacier where comparison can be made between the action of a mountain glacier and that of an ice sheet such as once covered this broad platform. It is also rare to find within such a restricted area so many forms of eruptive rocks, whether we consider them with reference to their lithologic contrasts or with reference to their widely varying modes of occurrence.

From the Three Sisters I descended the eastern flank of the Cascades to Camp Polk, and there turned back for a few miles along the Santiam road as far as a notable mountain, called in the vicinity the Black Butte. I somewhat regret now that I did not go farther eastward, across the Des Chutes river as far as Prineville, in order to to get a preliminary view of the sedimentary and probably lacustrine

formations through which that river runs. But, intent upon gaining more knowledge of the eastern flank of the Cascades, I chose the rugged route from the Black Butte northward. At the base of this butte is the head of the Metolias (White Salmon) river. It starts from two enormous springs, situated within a few hundred yards of each other, from which it flows away in a stream seventy or eighty feet wide, too deep to ford and with an exceedingly swift current. Several very large springs also help to swell its volume farther down. This river has been delineated on the maps as flowing from Mt. Jefferson: in reality it is only a small tributary of the Metolias that heads there. The course of the river from the Black Butte is a little west of north and it lies in a gradually deepening gorge for about twenty-five miles. It then suddenly swings at more than a right angle to the east-southeast and at length joins the Des Chutes. Its gorge becomes a cañon twelve hundred to fifteen hundred feet deep, and some difficulty was experienced in getting into it and out again.

At the bend of the Metolias I left the river and struck across the country to the Warm Spring Indian reservation. The only interest excited by the valley of the Metolias is in the curious question, How came the river to flow in such a direction, in apparent conflict with the natural slopes and topographic features of the country?

Entering upon the Warm Spring reservation was like entering another world. It is a typical plateau country, a mild desert, though not absolutely treeless, for the juniper, so characteristic of the plateaus, grows luxuriantly in some places. It is a land of mesa and cañon, with a trunk stream, the Des Chutes, running through a great cañon. The strata are nearly horizontal, with feeble dips of varying azimuth, the northward dip predominating. The beds are almost wholly—indeed, so far as seen, entirely—composed of tuff, usually fine, sometimes pulverulent, and all stratified by deposition in water. The beds disclosed at the reservation are presumed to be continuous with those which, in other parts of the valley of the Des Chutes and of the John Day river, have yielded an abundance of middle and late Cenozoic mammalian remains. Some remarkably even and uniform sheets of columnar basalt are frequently intercalated between these beds and are exposed in the cañon walls and upon the tops of the denuded mesas. The study of this series of deposits will in future be highly instructive, for it can hardly fail to disclose much information relating to the physical evolution of this part of the continent. That there has been a comparatively recent uplifting (possibly relative, if not absolute) of a very large region in these parts is suggested by many of the geological features.

A few miles north of the Warm Spring agency is a large tract, called the Mutton mountains. It contains an irregular and extensive group of hills or small mountains composed wholly, so far as seen, of rhyolite. It is much the largest field of rhyolitic eruptions which

I have thus far encountered in the Cascades. Lithologically it suggests nothing of special interest. The mass overlies the tufaceous beds of the Des Chutes, which are seen to be capped by this lava in many places.

After passing northward across this rhyolitic field I again ascended the Cascade platform in the direction of Mt. Hood. Here the first stormy weather for many weeks set in and travel was accomplished in the midst of rain, sleet, and snow and in the heart of the Cascade forest. Of course such travel was without much result, but I was anxious to reach the base of Mt. Hood, and, after the storm was over, to ascend it if possible. When the storm cleared, as it did after six days, it was evident that so much snow had fallen upon the upper cone that an ascent was impracticable. I therefore proceeded onward to East Portland and to Vancouver barracks, where I was most kindly received and cared for by the officers of the post. The indications being abundant that the season was too far advanced (September 15) and the rainy weather too imminent to permit of further profitable field work with a pack train, I determined to send my animals to their winter range and to disband my party, but also to take advantage of occasional good weather to make a brief reconnaissance of the gorge of the Columbia river through the Cascade platform. The animals were sent by railroad to Ashland.

After visiting the Cascade Locks and The Dalles, where many highly interesting facts are presented, I concluded my work for the season and returned to Washington.

FIELD WORK OF MR. J. S. DILLER.

The work of Mr. Diller was the continuation of the detailed geology of the district in the vicinity of Lassen peak. He has been engaged for three seasons upon it and has completed it in a highly satisfactory manner. The condensed results of his survey have already been embodied in a brief paper which will be published as one of the contributions to this volume.

EARTHQUAKE INVESTIGATIONS.

During the past year universal interest has been awakened in the subject of earthquakes by the great disaster at Charleston on August 31, 1886. Upon receiving information of its general character, Mr. W J McGee, of this Survey, was sent to Charleston, in company with Prof. T. C. Mendenhall, of the Signal Service, for the purpose of gathering such information as was practicable.

Upon my return from the field in October measures were taken for eliciting information from all parts of the country as to the effects of the earthquake. This work has been diligently pursued, and the data collected are very considerable. I think I am justified in say-

ing that this is the best observed earthquake that has ever occurred. In the collection of the data great zeal and intelligence were shown by my assistant, Mr. Everett Hayden, who has since resigned from the Survey. During the winter my time and attention have been fully occupied in this work and in putting the observations into form and in discussing them. A monograph upon the subject is now in progress and will be completed, I hope, in the course of a few months.

The Sonora earthquake of May 3 received careful attention. As soon as it was reported a large number of circulars were distributed and answers were received to most of them. As the focal point of this earthquake was in Mexico and as no expenditure of money upon work outside of the limits of the United States is allowed by law, the investigation was restricted to places within our own boundaries. The results obtained will enable us to draw with considerable precision the isoseismal lines, and there are numerous time reports, some of which will probably be of use in determining the velocity of propagation.

Very respectfully,

C. E. Dutton,
Captain of Ordnance.

Hon. J. W. Powell,
Director U. S. Geological Survey, Washington, D. C.

REPORT OF MR. LAWRENCE C. JOHNSON.

Department of the Interior,
U. S. Geological Survey,
Louisiana Division of Geology,
Potts Camp, Miss., July 1, 1887.

Sir: I have the honor to submit herewith my report for the fiscal year ending June 30, 1887.

With the exception of one trip across the lines of the formations from Starkville and through Aberdeen, Miss., to the Carboniferous in Alabama, attention was directed to the older Eocene, viz, the Claiborne, including the great Lignitic. An examination of the section through Aberdeen enabled me to establish the boundaries between the Tuscaloosa and Eutaw formations and the line between the Ripley, Flatwoods, and the Lignitic, accepting for the present the divisions made by Dr. Eugene W. Hilgard: the Ripley, the Rotten Limestone, the Tombigbee sands, and the Eutaw.

By sections across the State—one from the Carboniferous to the Mississippi bottom, through Aberdeen and Duckhill, and the other from Macon, Miss., to the salt water at the mouth of Pearl river—I have endeavored to show the relation of the geological strata of the

district and to construct an approximately correct profile of the surface.

In a paper presenting my general and final report on the year's work I have confined myself almost entirely to these older parts of the Eocene, and upon a map accompanying it I have shown the boundaries of the Claiborne and Jackson formations, the line of the Buhrstone rocks (the most prominent feature of the Claiborne), and the range of hills of the Lignitic, bounding and overlooking the Cretaceous.

The field of actual survey occupied twenty-seven of the interior and most inaccessible counties of the State, besides several others incidentally visited. Traveling was generally done by rail, but occasionally saddle horses or wagons were used. Very often these were tendered by people interested in the work, and guides and teamsters often served without compensation.

Very respectfully, your obedient servant,

LAWRENCE C. JOHNSON,
Assistant Geologist in Charge.

Hon. J. W. POWELL,
Director U. S. Geological Survey, Washington, D. C.

REPORT OF MR. W J M'GEE.

DEPARTMENT OF THE INTERIOR,
U. S. GEOLOGICAL SURVEY,
POTOMAC DIVISION OF GEOLOGY,
Washington, D. C., July 1, 1887.

SIR: I have the honor to submit my report upon the operations in field and office of the Potomac division of geology during the fiscal year ending June 30, 1887.

FIELD WORK.

District of Columbia.—Work in this field has not been carried on continuously, partly because the topographic map required as a basis for the geologic investigation was not completed until within the past few days and partly because the field study of this area has been made subordinate to administrative and other office duties and is performed during periods of relief from such duties. Accordingly, systematic operations have been limited to study of the terraces and of the deposits associated therewith on the south side of the Potomac—i. e., within the area covered by the portion of the map completed during last year. Meantime such observations as seemed expedient pending the completion of the portion of the map covering the country north of the Potomac and east of the Anacostia have been made casually from time to time, and the collection of notes, specimens, sketches, and

photographs illustrating the geology of the region has been considerably increased. At the same time observations have been extended eastward and northward, as they already have been to the southward and westward, and the deposits of the district have been correlated with those of the contiguous country as fully as is possible without final exhaustive study. Thus the data accumulated during the year, together with those acquired during preceding years, form a quite adequate basis for the final review of the entire field and the preparation of a formal report thereon as soon as the topographic map is engraved and printed.

Chesapeake bay and Susquehanna river.—Just after the beginning of the fiscal year inquiries relating to the possibility of artesian water supply at the head of Chesapeake bay were addressed to this office, and you specially authorized me to make such examinations as were necessary in order adequately to respond to these inquiries. Accordingly, a visit was made to Fishing Battery station, near Havre de Grace, Md., and from that point as a center of operations extended studies were made along both shores and over a considerable area on each side of the bay, as well as far into the plateau to the northward. The data collected during this examination proved to be of unexpected scientific interest, and it was found also that the inferences as to probable artesian flow deducible therefrom were applicable not only locally, but, with certain limitations, all along the "fall line" from the Delaware to the Roanoke; and accordingly it was thought desirable to revisit the locality, collect additional data, and secure such photographs, sketches, etc. as were required to illustrate the subject, and to then arrange the material for publication. This was done, and the memoir was completed in time for incorporation in the Seventh Annual Report of the Survey. Prof. Lester F. Ward accompanied me during the second trip to the locality, and his familiarity with the formations there exposed and the plant remains preserved within them proved of material assistance in determining the relations of the different deposits.

Acknowledgment is due to Maj. Thomas B. Ferguson, of the U. S. Fish Commission, for the use of a steam launch and crew during each of the visits to this locality. The means of transportation thus afforded greatly facilitated the work, which indeed could not have been otherwise completed within twice or thrice the time actually spent on the ground.

In the progress of this investigation certain questions arose as to the exact relations between the correlative processes of erosion and deposition in contiguous areas, and consequently between the topographic forms fashioned by erosion on the one hand and the deposit made up of the eroded materials on the other; certain essential questions also arose concerning deformation of the land in this region in recent geologic time and concerning the evidence of such deformation to be found in the behavior of the rivers; and finally there arose

important questions concerning the relations of the different Quaternary deposits of the northern part of the Middle Atlantic slope, not only over the low lying coastal plain, but in the river valleys embouching upon it. For the purpose of solving these questions a trip was projected up the Susquehanna river from its mouth to well within the glaciated area in northern central Pennsylvania, thence across the mountains to the Delaware, down that river to its embouchure into the bay, and finally across the State of Delaware to the point of departure. The purposes and conditions of this trip were similar to those of a journey up the Potomac river made two years ago and mentioned in the Sixth Annual Report of the Survey; and it was accordingly deemed best to make this journey also chiefly on foot. The trip was made during the month of June.

The results of this special investigation, particularly in the valley of the Susquehanna, are of high value: satisfactory answers to the questions which led to it were found and additional information which throws much light on the Quaternary history of the Atlantic slope was gained. A preliminary publication embracing a part of these results will appear at an early day.

The Charleston earthquake.—When the disastrous results of the earthquake of the 31st of August last in the Carolinas and Georgia were announced in the press dispatches of the next day, the desirability of carefully investigating the effects of the disturbance upon structures and upon the ground surface before they were obliterated was at once perceived, and you authorized me to proceed to Charleston as soon as communication was reopened for the purpose of making such observations as promised to be of value to students of seismology in final discussion of the earthquake. Accordingly, the morning of the 3d of September found me in Charleston, accompanied by a photographer. During the ensuing week observations were made as rapidly as possible, not only in Charleston and immediate vicinity, but also at Summerville, Ten-Mile Hill, and other points within the area most seriously shaken. Thirty-three large photographs, representing the effects of the disturbance upon buildings and upon the surface of the earth, together with several sketches, were secured, and notes were made upon several of the slighter secondary shocks and the accompanying detonations, which, continuing for some weeks, kept the already terrified people in a state of constant uneasiness and anxiety. Valuable information concerning the initial shock was also secured from a number of the intelligent citizens of both Charleston and Summerville. During the greater portion of the time spent in this vicinity I enjoyed the advantage and pleasure of association with an experienced student of seismology, Prof. T. C. Mendenhall, who carefully studied the phenomena attending the disturbance under the directions of the Signal Office.

It was soon found to be impossible to secure all the data required for a final discussion of the earthquake in the brief time available, and accordingly arrangements were effected to have the work continued. The laborious task was generously assumed by Mr. Earle Sloan, a citizen of Charleston and a mining engineer of experience and intelligence, who had already commenced independently a record of the more striking phenomena. A general plan for the work was developed, and Mr. Sloan spent some weeks in investigations within the central seismic area. The results of his studies were incorporated in a preliminary report duly transmitted to the office of the Survey; my own data were arranged in systematic form; and both were placed in the hands of Capt. C. E. Dutton, on his return from the Pacific slope, for final discussion. Although hastily prepared, Mr. Sloan's report is elaborate and full of significant detail, and must be ranked as one of the most valuable records of earthquake phenomena ever prepared by a single observer.

It is a pleasure to express my high appreciation of the signal service rendered to the Survey and to science by Mr. Sloan in the eminently satisfactory performance of the difficult task which he so cheerfully assumed—a task which, even under the most favorable circumstances, would have been attended with great difficulty, and which, performed as it was during the hottest and most oppressive season of an always enervating climate, at a time when the ordinary means of communication and transportation were seldom available and under circumstances so unusual and trying that the majority of the population were utterly prostrated and helpless, was one of such exceptional difficulty that its successful accomplishment commands the highest admiration.

Every possible assistance was courteously rendered me by a large number of the citizens of Charleston and Summerville, and it is a pleasure to acknowledge indebtedness to these gentlemen collectively; but I cannot avoid mentioning the special obligations under which I was placed by Professor Charles U. Shepard, jr., Dr. C. E. Manigault, Mr. W. T. Fisher, Mayor C. E. Courtney, Col. Joseph A. Yeates, and Col. William Gregg, both for valuable information and for facilities in prosecuting my studies.

Kansas.—The geologic investigation of southeastern Kansas was continued during the first half of the fiscal year by Mr. Robert Hay, in accordance with plans already set forth. During the months from July to October he was employed in the field in the counties of Bourbon, Crawford, Cherokee, Allen, Neosho, and Labette, Kans., and in contiguous parts of the counties of Vernon, Barton, and Jasper, Mo. The primary object of the work was to color geologically the topographic atlas sheets representing this area, and a careful study of the stratigraphy and paleontology of the region was essential to

the attainment of this object. Mr. Hay successfully accomplished this part of his task, and during the period mentioned collected data for a number of sections representing the stratigraphy and the general geologic structure of southeastern Kansas and western Missouri and for distinctively coloring the formations of the area on the sheets with which he was provided. In addition, Mr. Hay made a special investigation of the natural gas and petroleum which are now attracting attention in southeastern Kansas; and, after ascertaining the formations in which and the conditions under which gas and oil may be found, he prepared a memoir on the subject, designed especially for the use of citizens of the State, which was published during the winter by the Kansas State board of agriculture. The natural gas of this region, unlike that of many other fields, is used as an illuminant and is piped directly from the borings to dwellings and offices for that purpose. Mr. Hay also worked out in detail the distribution and the depth at various points of the Fort Scott cement bed—a water lime deposit of southeastern Kansas and western Missouri of considerable industrial importance.

Mr. Hay spent the months of November and December in reducing his notes and preparing sections and maps, which were duly transmitted to Washington and are now on file in this office. No special publications by the Survey are likely to grow out of Mr. Hay's investigations until his geologically colored atlas sheets are issued.

Eastern Virginia.—The study of the Tertiary formations between Richmond and the mouth of James River, made by Mr. Ira Sayles under your general directions during the past summer, was, in accordance with your instructions, carried on under my immediate supervision. Two objects were kept in view, viz, (1) the determination of the extent and value of the natural fertilizers (chiefly greensand or glauconitic marl) of the region and (2) the definition and correlation of the various formations and the investigation of the conditions of their genesis required to permit correlation of the topographic forms of the Piedmont region with the deposits of the coastal plain in the manner already indicated.

While Mr. Sayles's work was one of reconnaissance rather than of survey and while his results are by no means final, enough was done to prove that the greensand, which is one of the more valuable natural fertilizers of the world and destined to greatly promote agricultural interests at no distant day, may be found in practically inexhaustible quantity and within easy reach of mining operations over a large area on both sides of James River. Some additions to our knowledge of the origin and relation of the Tertiary deposits of the region were also made, and a collection of fossils was accumulated for use in correlating these deposits with those of other regions. The fossils have been transferred to the Cenozoic Division of Invertebrate Paleontology, and the remaining material, which was placed

in my hands when Mr. Sayles was assigned to other duty some weeks since, will be utilized as the work of the division progresses.

OFFICE WORK.

Geology of Chesapeake bay.—The first important office task of the fiscal year was the preparation of a report embracing the results of the work already described about the head of Chesapeake bay. This paper was completed in time for incorporation in the Seventh Annual Report of the Survey.

International Congress.—During the year there have been several meetings of the American committee of the Congrès Géologique International, and I had the honor to attend one of these (at Albany, on April 6) as your representative. In addition much attention has been given to the general subject of geologic taxonomy and cartography, and the various important questions involved therein have been carefully considered under your constant direction. The whole subject, however, yet remains in an inchoate condition, and it has not been deemed wise to make final publications relating to the subject without the most mature consideration. Accordingly, the proposed cartographic bulletin mentioned in the last report of this division has not yet been sent to press.

The thesaurus of American formations.—As during the last fiscal year, work upon the thesaurus has been limited to the gleaning and recording of data encountered in the course of current reading which will finally be incorporated therein. The material already accumulated is kept constantly arranged and is found of great service in certain of the lines of work pursued in the division.

Mr. Hay's bulletin.—During the early part of the year the report of a reconnaissance made by Mr. Robert Hay in southern central Kansas during the preceding fiscal year was revised, some preliminary matter was added, and the whole was arranged for the printer and handed in for publication.

The geologic map of New York.—Unexpected difficulties have been encountered in constructing the base for the geologic map of New York, prepared under the supervision of Prof. James Hall, the State geologist, and described in a previous report. There are no maps extant representing the railways, canals, and rivers of the whole of the State with sufficient accuracy for the desired purpose; and it has accordingly been necessary to compile such data from a great variety of sources, and delays have sometimes resulted from the difficulty of finding the most trustworthy sources of information. The work has, however, been pushed forward as rapidly as possible by Mr. J. H. Kleinroth, to whom the task of preparing the base has been intrusted, and satisfactory progress has been made.

The history of American surveys.—Although the greater part of the material required for the preparation of the History of American

Scientific Surveys mentioned in my last report is now in hand, there are two or three important surveys yet remaining to be described; and until sketches of these are received it will be impossible to complete the compilation. Nearly all of the material thus far collected has been generously contributed by gentlemen in different parts of the country who are thoroughly familiar with the unwritten as well as the written history of the surveys which they describe; and delay in sending in the material has resulted from the inability of some of these gentlemen, who are under constant pressure in other directions, to complete their contributions as promptly as was anticipated. It is believed that the small amount of additional material required will be obtained in time to permit the completion of the history during the coming autumn. As was mentioned in the last report, independent publication of the sketches of particular surveys is encouraged, and several such sketches have already appeared. During the year another has been issued in accordance with this plan, viz, an exhaustive history of the New York State land survey and survey of the Adirondack region, by the originator and present director, Verplanck Colvin.

The bibliography of Texas.—Mr. J. B. Marcou has been occupied upon the bibliography of Texas, Arkansas, Louisiana, and Indian Territory most of the year, and eminently satisfactory progress has been made. The examination of relevant scientific literature accessible in Washington was completed early in the year; but, in order that the work may be exhaustive, it was deemed necessary to examine also the libraries of other literary centers. Accordingly, Mr. Marcou visited Boston, Cambridge, New Haven, New York, and Philadelphia, and scanned the contents of the leading libraries in each of these cities, securing thereby a large amount of additional material. The material has thus become more voluminous than was anticipated, the number of titles having been increased during the year from 1,500 to about 2,500. For this reason it has been found necessary to modify somewhat the plan for the bibliography and to revise and change the scope of the annotations. A large portion of the matter has been so revised. The bibliography will be ready for the press within a few months.

A memoir on the geology of Texas, prepared by Dr. R. H. Loughridge, was held in this division for some time. As indicated in previous reports, it was the original intention to revise and publish this sketch as a bulletin of the Survey; but certain important questions relating to the structure of Texas remained unsolved and it appeared unwise to send the matter to press without further field examination. Now, during the year, extensive field operations were carried on in Texas by the Mesozoic division of invertebrate paleontology, and exceedingly important results were secured; and it became evident that the best disposition to make of the memoir was to place it in the hands of Dr. White, of the division above mentioned. This has ac-

cordingly been done. It is now improbable that the memoir will be published in its original form.

During the past year administrative duties of a general character, such as absorbed a considerable part of my time and energy during the preceding year, have not only continued but increased. Accordingly, much of my time has been spent in detail work which, while necessary and important, does not require specific mention here. A sufficient recompense for this labor has ever been found in the intimate association with yourself resulting therefrom and in the constant assistance and encouragement in the more strictly scientific work of the division which I have in consequence been enabled to receive from you.

I have the honor to be, sir, with great respect, your obedient servant,

W J McGee,
Geologist in Charge.

Hon. J. W. Powell,
Director U. S. Geological Survey, Washington, D. C.

REPORT OF PROF. O. C. MARSH.

Department of the Interior,
U. S. Geological Survey,
Division of Vertebrate Paleontology,
New Haven, Conn., July 1, 1887.

Sir: I have the honor to submit the following report of the work of this division during the past year:

In compliance with your general instructions, I have continued the systematic work of collecting vertebrate fossils in the West and investigating those of special interest to science. The objects particularly kept in view in this work, their relative importance, and their value to the advancement of science were explained at length in my last annual report.

The work in the West during the last year has been systematically prosecuted and the results are satisfactory. In the Jurassic deposits of Wyoming two parties have been engaged in collecting fossils, one securing the remains of dinosaurian reptiles and the other making especial search for mammals. In southern Colorado, in essentially the same horizon, another party has continued work at the localities explored in previous years, and important collections have been made, which add valuable material for the investigations now in progress.

During the last season I visited all these localities in Wyoming and Colorado, and various others at intermediate points, in the same Atlantosaurus beds, and found additional evidence that these deposits form one of the best marked horizons in the Rocky Mountain

region and one of the richest in vertebrate fossils known in any part of the world.

The exploration of the Tertiary basins of Dakota was begun last year and has been continued to the present time, with important results, which cannot be fully estimated until the extensive collections secured have been more carefully investigated. Many tons of the remains of huge Brontotheridæ and other Miocene mammals have been obtained. Not a few of the forms represented are new to science and some of them are of much scientific interest.

The work on the monographs now in preparation has made good progress during the past year. The memoir on the Sauropoda will soon be ready for publication and the others are well advanced.

Very respectfully,

O. C. MARSH,
Paleontologist in Charge.

Hon. J. W. POWELL,
Director U. S. Geological Survey, Washington, D. C.

REPORT OF MR. C. D. WALCOTT.

DEPARTMENT OF THE INTERIOR,
U. S. GEOLOGICAL SURVEY,
PALEOZOIC DIVISION OF INVERTEBRATE PALEONTOLOGY,
Washington, D. C., July 1, 1887.

SIR: I have the honor to present the following report of operations conducted under my charge during the fiscal year ended June 30, 1887.

FIELD WORK.

The field operations for the year were: (1) the continuation of the study of the strata of the Devonian system in southern New York and their faunas; (2) the study of Cambrian strata and the collecting of fossils in East Tennessee; (3) the study of the Potsdam formation about the Adirondack mountains, New York; (4) the study of the geology of Washington county, N. Y., with reference to the "Upper Taconic" rocks of Dr. E. Emmons; (5) an examination of certain strata of Cambrian age in Dutchess county, N. Y.; (6) the collecting of fossils from typical localities of the Trenton formation in New York State; (7) an examination of the quartzite on the west side of the Green mountains, Vermont.

Prof. H. S. Williams's field work was confined to Seneca, Cayuga, Chenango, Madison, and Oneida counties, N. Y., where he studied sections and collected fossils for the purpose of filling out the details of the geologic and geographic distribution of the Middle Devonian faunas in central New York. Mr. C. S. Prosser assisted in the field

work and Mr. S. D. Harris added another station in Chautauqua county, N. Y., to obtain data on the Upper Devonian.

Mr. Cooper Curtice, paleontologic assistant, was employed during the month of July in examining sections of Cambrian strata and collecting fossils in the vicinity of Rogersville and Greeneville, Tenn. This work was closed by the resignation of Mr. Curtice, August 1.

On the 9th of June, 1886, I began the study of the Potsdam formation about the Adirondack mountains in Jefferson county, N. Y. Thence I passed through St. Lawrence, Franklin, and Clinton counties during the month of June, collecting fossils and measuring sections of the Potsdam formation at the best exposures.

From the 1st to the 7th of July I was engaged in taking a section of the Chazy formation on the Isle la Motte, in Vermont, for the purpose of comparison with the section above the Potsdam formation in Clinton county, N. Y. I then went to Beauharnois, in the province of Quebec, on the St. Lawrence river, and there obtained a collection of fossils from the Potsdam sandstone and the overlying Calciferous sandrock.

The Potsdam formation at Au Sable Chasm and in the vicinity of Keeseville, Essex county, N. Y., was next studied, quite a collection of fossils and a very good geologic section being obtained.

The next section was taken at Whitehall, in Washington county, and from there a reconnaissance was made to the eastward, partially across Washington county, to determine the possibility of obtaining a section of the Cambrian rocks that extend into the county from the north. On returning an examination was made of an outlier of Potsdam sandstone, on the western side of South bay, at the head of Lake Champlain.

Not finding the Cambrian section well developed in the northern part of Washington county, I next examined a section crossing the town of Greenwich, in the southern part of the county, and there obtained good results, as there was one locality already known from which Cambrian fossils had been obtained that could be used as a known starting point in a section. I then decided to make an examination of the Cambrian formations in Washington county, including the typical areas of Dr. E. Emmons's "Upper Taconic" rocks, and to map their lines of outcrop. This was continued up to October 21. I rode over 600 miles on a buckboard within the limits of the county and examined many areas between the roads by crossing them on foot. The results of the work were the discovery of eighty-two localities of Cambrian fossils within the county and eight localities of Hudson fossils in strata that were faulted amidst the areas of Cambrian strata. Three great fault lines were traced across the county and the limits of the Cambrian and Silurian (Ordovician) rocks were determined on both stratigraphic and lithologic evidence.

The examination of the strata was carried across the State line into Vermont sufficiently far to identify the great belts of strata that pass across the line. Two localities of Cambrian fossils were discovered in strata colored "Hudson River group" on the geologic map of Vermont (1861) and the geologic age of the roofing slates was determined both in Vermont and New York.

My last work in Washington county was to visit a locality of Potsdam sandstone, situated 900 feet above the surface of Lake Champlain, within the township of Dresden.

During the latter part of October three reported outcrops of Potsdam formation in the Mohawk valley were examined, with indifferent results.

I then proceeded to Poughkeepsie, N. Y., and examined the outcrops of Cambrian rocks north and south of the city with Prof. W. B. Dwight, of Vassar College. We visited all the localities known to him, and at Stessing mountain, in the northern part of Dutchess county, we discovered that the so-called Potsdam sandstone contained fossils from the Middle Cambrian fauna and that it should be referred to the Taconic horizon of the Cambrian.

During the month of June an examination was made of the strata of the Chazy formation in the vicinity of Fort Cassin, Vt., and arrangements were made with Mr. William P. Rust for the collecting of a large series of fossils at Ft. Cassin. I then proceeded to Middlebury, Vt., and, with Prof. H. M. Seely, visited the reported locality of Middle Cambrian fossils at Lake Dunmore. This, with a visit to the quartzites east of Arlington, Vt., in Sunderland, in search of fossils to determine the geologic age of the quartzite, closed the field work for the year.

Mr. William P. Rust, of Trenton Falls, N. Y., was employed during the summer to collect fossils from the Trenton and Hudson series of strata in central New York, and in December he sent in a large collection of specimens, neatly worked up and ready for study. The collection is a fine addition to the reference and exhibition collections and includes from the—

	No. of specimens.
Calciferous formation	6
Black River Limestone formation	687
Trenton Limestone formation	2,013
Hudson formation	986
Clinton formation	138
Total	3,830

OFFICE WORK.

Prof. H. S. Williams continued his studies on the Devonian faunas of New York State and also identified a collection of Devonian fossils made by Mr. H. R. Geiger in Maryland and Virginia.

During the field season Mr. J. W. Gentry remained in charge of the office, attending to correspondence, cataloguing specimens, copying field notes by type writer, etc.

On returning in November I began writing out field notes, but was soon interrupted by the removal of my office and laboratory from the two small rooms in the south tower of the National Museum to a larger office and laboratory in the southwest tower. This change adds greatly to the facilities for doing work and enables me to handle the large collections without loss of time or labor.

The National Museum authorities continue to furnish all necessary facilities for the proper care of the collections, including an assistant.

In January the study of the collections of Cambrian fossils from Washington county, N. Y., was begun, and descriptions of the new forms have been written and lists prepared of the species, to accompany a report on the geology of the county. The latter was advanced as far as the data obtained would permit, and a geologic map of the county was prepared. A few days more of field work in the southern townships will complete the description of the geology and enable me to prepare the report for publication.

A short paper, on the "Fauna of the 'Upper Taconic' of Emmons in Washington county, New York," was prepared during the month of May, and, with one plate of illustrations, was sent to the American Journal of Science for publication.

A collection of fossils from the Clinton formation of the Silurian system in Alabama was worked up; the species were identified and lists were furnished to Mr. I. C. Russell. A small collection of Silurian fossils from New Hampshire was identified for Prof. R. Pumpelly. A few specimens from Oregon were studied for Mr. J. S. Diller, and also for Mr. H. W. Turner, of the California division. The Carboniferous and Silurian fossils collected by Mr. George H. Eldridge in Colorado were looked over and lists of the species were sent to him.

Some progress was made on the preparation of material for the study of the Upper Cambrian faunas prior to February 15, but, after that date, owing to the want of an assistant to do the mechanical work, very little was accomplished.

As honorary curator in charge of the collections of the invertebrate Paleozoic fossils of the U. S. National Museum, I gave attention at various times during the year to the arrangement of the collections, and a large amount of material collected by the Geological Survey was labeled and transferred to the Museum. This includes (1) the collection of Mr. I. C. Russell, from the Clinton and Trenton formations of Alabama, containing 22 genera, 26 species, and 190 specimens; (2) the collection of Mr. H. R. Geiger, from the Clinton and Oriskany formations of Virginia and Maryland, containing 6 genera, 6 species, and 23 specimens; (3) the collection

of Mr. N. H. Darton, from the Lower Helderberg formation of New York, containing 19 genera, 21 species, and 113 specimens; and (4) the following collections made by myself: (*a*) from the Trenton formation of Nevada, containing 19 genera, 24 species, and 142 specimens; (*b*) from the Pogonip formation of Nevada, containing 31 genera, 68 species, and 1,202 specimens; and (*c*) from the Taconic series of Washington county, New York, containing 23 genera, 35 species, 2 varieties, and 1,152 specimens.

By the resignation of Mr. Cooper Curtice, August 1, I was deprived of a valuable assistant. December 1, Mr. E. H. Sargent began work as a general assistant. He proved to be capable and useful; but, owing to the lack of funds, he was not retained after February 15. Mr. E. J. Akin was detailed from the topographic division to assist in the labeling and recording of specimens, and continued at the work from February 5 to May 24, 1887. Mr. Ira Sayles reported to me March 15 and was assigned work in connection with the recording of specimens from the Upper Cambrian formations. This, with the cataloguing of species, occupied his time to the end of the fiscal year.

The following publications, made on the results of studies carried on in this division, appeared during the year:

"Classification of the Cambrian system of North America," Charles D. Walcott, Am. Jour. Sci., 3d ser., Vol. XXXII, Art. 16, pp. 138–157, 9 figures, August, 1886.

"Cambrian age of the Roofing Slates of Granville, Washington County, N. Y.," Charles D. Walcott, Proc. Am. Assoc. Adv. Sci., Buffalo meeting, August, 1886, pp. 220, 221, Salem Press, December, 1886.

"The Taconic system," Charles D. Walcott, Am. Jour. Sci., 3d ser., Vol. XXXIII, p. 153, February, 1887.

Very respectfully,

CHARLES D. WALCOTT,
Paleontologist in Charge.

Hon. J. W. POWELL,
Director U. S. Geological Survey, Washington, D. C.

REPORT OF DR. C. A. WHITE.

DEPARTMENT OF THE INTERIOR,
U. S. GEOLOGICAL SURVEY,
DIVISION OF MESOZOIC PALEONTOLOGY,
Washington, July 1, 1887.

SIR: I have the honor to submit the following report of the work done in my division during the fiscal year ending June 30, 1887. The office work of the division has consisted of studies of the various collections of fossils received during the year and of those which were previously in its possession, the arrangement of the collections in the museum, the preparation of the results of those studies

for publication and for the use of chiefs of other divisions, and of the usual office routine work. The field work of the division for the year has been devoted to the Cretaceous formations of Texas and the collection of fossils from the same for systematic study.

FIELD WORK.

On account of the late date at which the annual appropriation was available, the field work was not begun until August. On the 5th of that month Mr. Hill proceeded to Texas with instructions to collect fossils from the Cretaceous formations of the central and northern portions of that State and to make notes of the stratigraphical relations of the different divisions of the Cretaceous series with one another. His work for the season was confined mainly to Grayson, Denton, Tarrant, Dallas, Comanche, and Travis counties, but various other counties were visited.

Early in October I joined Mr. Hill at Austin and proceeded to review with him his field work of the two preceding months and to make additional observations with reference to the objects of that work. In furtherance of these objects I traversed the western portion of the State along several extended lines and gathered important data there, especially concerning the relation of the Cretaceous formations, which are continuous with those of the Rocky Mountain region to the northward, to those in eastern Texas, which are continuous with the Cretaceous formations of the other Gulf States to the eastward. During this reconnaissance various points along the valley of the Rio Grande were visited, and the formations which were especially under investigation were in some instances traced into the Republic of Mexico for the purpose of making the observations more complete. From these observations, in connection with others previously made, general conclusions have been reached, of which the following is a brief statement.

The Cretaceous series of eastern Texas is separable into two principal divisions, an upper and a lower, each having distinct and well marked paleontological characteristics. A study of their fossil faunas respectively has shown that while the formations of the upper division may be correlated, at least in a general way, with the Cretaceous formations of the great interior region, and also with those of the Gulf States, the lower division cannot be so correlated; that is, the lower division belongs to a lower horizon than that of any other Cretaceous strata of North America at present known, except the older Cretaceous strata of the Pacific coast and perhaps those of the yet comparatively little known Potomac group of the Atlantic coast. Strata of the lower division of the Texas Cretaceous have not been recognized to the eastward of that State, nor farther northward than southeastern Kansas, but they extend to western Texas and over into Mexico, where they are overlaid by the representatives of

the Dakota, Colorado, Fox Hills, and Laramie groups, as they are overlaid by the formations of the upper division in eastern Texas.

Although the upper division of the Texas Cretaceous series has been correlated by means of some of its fossils with the western Cretaceous series from the Dakota to the Fox Hills groups, inclusive, the faunas of the respective series present great differences. This is conspicuously the case with the fauna of the representative of the Fox Hills group in western Texas as compared with that of the uppermost member of the upper division (the representative of the Ripley group) in eastern Texas.

My plan for the field work in Texas embraced the tracing to the southward of the eastern and western Cretaceous series, respectively, until their contact or their physical relation to each other should be discovered. This part of my plan was based upon the fact that the trends of the eastern and western series, respectively, rapidly converge in southern Texas, and upon the consequent hope that the two series might be found in contact or in close proximity within the limits of that State or the adjacent part of Mexico. It is still believed that a solution of the important question of their relation to each other may be reasonably looked for there. It is to be hoped especially that the next season's field work will reveal the true relation of the Fox Hills and Laramie groups on the one hand with the Ripley Cretaceous and the marine Eocene on the other.

The collections of fossils which were made during the last season from the Cretaceous rocks of Texas are now being studied, and the results of this work when published will constitute a large addition to our knowledge of the faunas of that geological period and will be of important service in the future geological work of the State.

OFFICE WORK.

During the early part of the fiscal year considerable time was devoted to the collation of published facts and statements bearing upon the subjects which I have under investigation, especially upon a proposed comprehensive work on the Laramie group.

During the months of November, December, and January my two assistants, Mr. Hill and Mr. Boyle, were engaged upon the arrangement of the collections of Texas Cretaceous fossils, while I devoted that time to their study and the preparation of new forms for publication. Numerous illustrations have been drawn for this work by Mr. J. L. Ridgway and Mr. F. W. Von Dachenhausen, who were detailed for that purpose.

On January 24 Mr. Hill, by your direction, was assigned to work outside of my division; but Mr. Boyle has continued the work upon the collections and their museum classification and arrangement. He has also taken charge of the clerical and routine museum work of the division.

During most of the time from February to June I was engaged on the preparation of Bulletin 50 of the Survey, entitled "On invertebrate fossils from California, Oregon, Washington Territory, and Alaska, with remarks upon the formations which they represent," the manuscript of which is now in the hands of the printer. The material upon which this work is based was in part obtained by members of the Survey and in part furnished by Prof. J. S. Newberry. Smaller collections for this work were also received from Prof. Thomas Condon and Mr. E. E. Howell, respectively.

PUBLICATIONS.

The following are the titles of my writings upon geological and paleontological subjects which have been published during the last fiscal year:

1. On the Fresh-water Invertebrates of the North American Jurassic, Bulletin No. 29, U. S. Geological Survey, 41 pages and 4 plates.
2. On the Relation of the Laramie Molluscan Fauna to that of the succeeding Fresh-water Eocene and other groups, Bulletin No. 34, U. S. Geological Survey, 54 pages and 5 plates.
3. "On the age of the coal found in the region traversed by the Rio Grande," Am. Jour. Sci., 3d ser., Vol. XXXIII, pp. 18–20.
4. "On new generic forms of Cretaceous mollusca and their relation to other forms," Proc. Acad. Nat. Sci. Phila. for 1887, pp. 32–37 and 1 plate.
5. "On the Cretaceous formations of Texas and their relation to those of other portions of North America," Proc. Acad. Nat. Sci. Phila. for 1887, pp. 39–47.
6. "On the inter-relation of contemporaneous fossil faunas and floras," Am. Jour. Sci., 3d ser., Vol. XXXIII, pp. 364–374.

Respectfully submitted.

CHARLES A. WHITE,
Geologist in Charge.

Hon. J. W. POWELL,
Director U. S. Geological Survey, Washington, D. C.

REPORT OF MR. W. H. DALL.

DEPARTMENT OF THE INTERIOR,
U. S. GEOLOGICAL SURVEY,
CENOZOIC DIVISION OF INVERTEBRATE PALEONTOLOGY,
Washington, D. C., July 1, 1887.

SIR: I have the honor to submit the following report for the year on the operations of the division under my charge.

The force engaged in the work of the division during the year, exclusive of the writer, has comprised Dr. Robert E. C. Stearns, assistant paleontologist; Frank Burns, assistant geologist; and, for varying short periods, Messrs. R. Stuart, J. B. Crowe, and R. T. Hill, all of the Survey.

The work of the division has comprised field work and office routine work.

FIELD WORK.

During the early part of the year Mr. Frank Burns continued the task of exploring for fossils the localities from which the earlier paleontologists of the United States had collected or described Cenozoic fossils, with the object of recovering the identical species, often imperfectly or erroneously characterized by the original authority. Mr. Burns remained at work on the Lower Potomac until forced by illness, resulting from malaria, to retire from the field. His collections were abundant and valuable, and, should the allotment for this division warrant it, the work will be taken up again at a suitable moment.

During February and March of 1887 the writer continued field work begun two years ago in Florida, by proceeding to Tampa and thence by small boat along the western coast of Florida to Punta Rassa, and thence up the Caloosahatchee river, where some time was devoted to the examination and exploration of the fine beds of Pliocene and Post-Pliocene marls which are exposed on the upper part of this river for some ten miles below Fort Thompson. About four hundred species of fossils were obtained, about four times as many as were previously known from this region, including a number of novelties. About one hundred species were obtained at other localities, chiefly at Ballast Point, Tampa bay, and at White Beach, Little Sarasota bay. Numerous geological notes were made, adding largely to the knowledge of the structure of this part of the State. The data afforded materials for observations on the geology of southwestern Florida read before the National Academy of Sciences at its meeting of April, 1887, and for papers presented to the Philosophical and Biological Societies of Washington. The detailed report on the paleontological material is in preparation for publication.

OFFICE WORK.

Routine work consisted during the year, as during that which preceded it, of the identification, classification, cataloguing, and preparation for study or exhibition of the Cenozoic fossils and related recent forms which have accumulated during the history of the Survey. The amount of arrears has been very great and is being satisfactorily diminished. When I undertook this duty, somewhat more than two years ago, there had been, during some twenty years of Government explorations and collections from various sources, out of the material received at the Museum, some 42,440 entries made in the register of the department. This corresponds by a fair estimate to about 106,120 specimens which had been administered upon, or an average of 5,306 specimens annually. All beyond this had accumulated in boxes, barrels, and packages, which had hardly been so much as opened. Having had ample clerical assistance, partly furnished by the National Museum, I was able to state in my report for 1885–'86 that in the year referred to 18,638 entries had been made in

the register, corresponding to about 46,595 individuals; in the year 1886–'87. with but little clerical assistance available for critical work, though more specimens were handled, not so many reached the final stage of registration, and the total for the year is 10,530 registrations, covering some 26,325 specimens, or an annual average for the two years of about 36,460 specimens, about seven times as great as the annual average of the preceding twenty years.

This is a result with which there is no reason to feel dissatisfied, although with the assistance of one or two efficient clerks it could be largely exceeded. When the arrearages are made up the assistance of one good clerk will be ample to keep abreast of the ordinary receipts of the division. It is to be observed that no new arrearages have been permitted to accumulate, all new material being attended to at once.

The members of the force have been indefatigable in their endeavors to expedite the work assigned to them, but the want of proper work rooms is severely felt. The foul air and poor ventilation of the gallery, where most of the work is done, have had a decided and injurious effect on the strength and activity of those employed there.

I am glad to be able to state that, when the collection is at last in a state to be freely consulted and studied, there will be few, if any, in the world which, for the American area, will equal it and none which will surpass it, and its superiority will increase with the work of the Survey from year to year.

During the year many inquiries from students and others have been received and answered: some three hundred and fifty letters have been written, and information and duplicates for study have been freely put at the service of all applicants properly vouched for. Among others, information or assistance has been afforded to the following persons and institutions, not including members of the Survey:

Agassiz, Prof. Alex., Massachusetts.
Aldrich, T. H., Ohio.
Beecher, C. E., New York State Museum.
Binney, W. G., New Jersey.
Boury, E. de, France.
Cooper, J. G., California.
Dominion Geological Survey, Canada.
Dugès, Prof. A., Mexico.
Flint, Dr. Earl, Nicaragua.
Greegor, Isaiah, Florida.
Greely, General A. W., U. S. A.
Heilprin, Prof. A., Pennsylvania.
Hemphill, H., California.
Henshall, Mrs. J. A., Kentucky.
Hitchcock, Prof. C. H., New Hampshire.
Hodge, C. F., Maryland.
Jones, E. E., Tennessee.
Leidy, Prof. Joseph, Pennsylvania.
McCormick, Dr. J. L., Tennessee.
Mazyck, W. G., South Carolina.
Merriam, Dr. C. H., Washington, D. C.
Mexican Geographical Commission.
Mills Seminary, California.
Moser, Lieut. J. F., U. S. N.
Newlon, Dr. W. S., Kansas.
Pilsbry, H. E., Iowa.
Redway, J. W., Pennsylvania.
Rush, Dr. W. H., U. S. N.
Ryder, W. P., Maryland.
Sandberger, Prof. H., Bavaria.
Simpson, Charles T., Nebraska.
Sterki, Dr. V., Ohio.
Swan, J. G., Washington Territory.
Todd, Aurelius, Oregon.
Westgate, W. W., Texas.
Wetherby, A. G., North Carolina.
Whiteaves, J. G., Ottawa, Canada.
Wilson, Thomas, Washington, D. C.

During the year the writer has contributed some ten or twelve articles on topics connected with the work, but not official, to various scientific periodicals or publications; but the pressure of routine work has prevented him from attempting any more important research than that upon the Floridian fossils already referred to as in progress.

NEEDS OF THE DIVISION.

Two things are much needed by the division: (1) a competent assistant for purely clerical work; (2) some one with a preliminary knowledge of paleontology, to whom the simpler part of the biological work may be gradually delegated and who may be in time qualified to undertake single handed creditable work of original research.

That the stores of the collection contain full materials for fruitful study in many directions cannot be questioned. At present the paleontologist in charge is so bound by the mass of routine work that he is in danger of being debarred from nearly all opportunities for original research.

I remain, very respectfully yours,

WM. H. DALL,
Paleontologist in Charge.

Hon. J. W. POWELL,
Director U. S. Geological Survey, Washington, D. C.

REPORT OF MR. LESTER F. WARD.

DEPARTMENT OF THE INTERIOR,
U. S. GEOLOGICAL SURVEY,
DIVISION OF PALEOBOTANY,
Washington, D. C., July 1, 1887.

SIR: I have the honor to submit the following report of the operations of the Division of Paleobotany during the fiscal year ending June 30, 1887.

FIELD WORK.

Only eight days (October 16–23, 1886) have been devoted to field work. The first four days of that time were spent in the city of Baltimore, under the guidance of Prof. P. R. Uhler, who is familiar with many interesting localities, studying the outcrops of Potomac strata at that place, making collections of fossil plants at certain points, and examining Professor Uhler's collections. The fossils obtained by me were subsequently sent to Professor Fontaine, at the University of Virginia, to be incorporated in the monograph he is preparing on the flora of the Potomac formation for publication by the U. S. Geological Survey. Professor Uhler also generously allowed me to ship to Professor Fontaine, for the same purpose, his entire collection of fossil plants, made during many years of energetic study of the geology of Baltimore and vicinity.

During October 21 to 23 I accompanied Mr. W J McGee to the head of Chesapeake bay to visit the bluffs in that vicinity, where he had observed an extensive exposure of upper Potomac strata. In July Mr. McGee had submitted for my inspection some imperfectly preserved impressions of leaves collected by him at Grove Point on the eastern shore of the bay, and I had hoped to find other beds in that region in which the leaves should be determinable. The Fish Commission steam launch at the battery near Havre de Grace was kindly placed at our command by Maj. T. B. Ferguson, and we visited a number of points of special interest, including the one at which the plants were obtained. The time was largely taken up in photographing the bluffs, and no localities were visited except those already examined by Mr. McGee. I was unable in the time allowed to find any fossil plants except at Grove Point, and, although they were here seen at several places at some distance from one another and occupying somewhat varying vertical positions with reference to the strata, I could find no place where they were embedded in a firm matrix or where the sandy clay did not crumble away at the least disturbance. By great care I obtained a few tolerable specimens, which were securely wrapped and brought back by hand in a basket. I have not yet given this collection a systematic study, but from a casual examination it confirms the opinion I expressed with regard to the one submitted to me by Mr. McGee, namely, that the flora of these clays differs widely from that of the beds seen by me, and now so thoroughly studied by Professor Fontaine in Virginia, and, so far as I can judge, it points to a later date for their deposition. Indeed, as admitted by Dr. Newberry, who saw Mr. McGee's specimens, it bears considerable general resemblance to that of the Raritan clays of New Jersey. It was, therefore, decided not to ask Professor Fontaine to embody these imperfect collections in his monograph, and I hope at some future time to have a better opportunity to investigate the region in question with special reference to discovering more satisfactory deposits of vegetable remains.

OFFICE WORK.

Mr. C. D. White has had the immediate supervision of the paleontological drawing, but I have been obliged to have him do other kinds of work during a considerable part of the time. He was assisted by Mr. Herman Birney from August 9 to September 4, 1886, and by Mr. Daniel W. Cronin from November 5 to the end of the fiscal year. A large number of new drawings have been made, but a fully equal number of specimens remain to be drawn before the types of Laramie plants already selected will be completed. Until this part of the work shall have advanced considerably further it will not be an economical use of time for me to resume the study of the fossil plants with a view to describing them for publication.

In view of this I have thought best to use all the means at my command in advancing the work on my prospective compendium of paleobotany. Accordingly I employed during the fall and winter a number of copyists, who were instructed in cataloguing systematic works for the slip index of species, which is to be the basis for all the compilations and analytic discussions in that work. Having no one specially trained in bibliography, I was obliged to assign to Mr. White the duty of keeping these copyists employed by supplying them with the works in question from the libraries to which I had access. As these works became more rare and this branch of the work increased, it became impossible to keep so many clerks employed, and they were gradually dropped from the roll. Thus Miss Katie Clark and Mr. G. W. Stewart worked from August 23 to December 31, 1886; Miss Lottie Schmidt, from September 1, 1886, to May 15, 1887; and Mr. J. T. Jones, from January 3 to February 28, 1887. Mr. Bruno Müller resigned on October 31, 1886, and Mr. George Geddes on April 15, 1887.

In this way a large amount of this preliminary work was accomplished. Being performed, however, by unskilled labor, it needed careful revision, and as I had no one to whom I could assign this duty I was obliged to perform it myself, and I found that it left me very little time for other work. With the assistance of Miss Annie S. Moorhead, who devoted her whole time to placing in the slip index such slips as required no correction, I succeeded in keeping the index in an available condition for use at all times. It now contains about 150,000 slips, and even in its present state affords to those who can have access to it the most complete and valuable record of the work that has been done in paleobotany anywhere to be found.

As many works could not be consulted at Washington, it has been a regular part of my plan to search through the catalogues of different publishing houses in Europe and America and to ask for the purchase of all such as are therein advertised for sale. One invoice of such works was received in September and one in October, together amounting to some three hundred pamphlets and books, and four other orders were prepared in March and April.

Being sure that many such works were to be found in the libraries of Harvard University and in those of Boston, I made a journey thither under your orders to visit them, and spent the last half of May in searching for them. I was quite successful, but left much to be done, which, through the hearty co-operation of Professor N. S. Shaler, I was able to leave in the hands of his trained assistant, Mr. Ralph S. Tarr, who will complete the work in connection with his other duties.

Prof. Leo Lesquereux has continued the work on which he was engaged at the date of my last administrative report. In a recent communication from him he announces that his monograph of the flora of the Dakota group is practically completed and will soon be sub-

mitted for publication. I have continued to send him the accumulations of fossil plants arriving at the National Museum chiefly from the various parties of the U. S. Geological Survey, which I have not time to study at present, and he has undertaken to determine them, responding to all inquiries with his characteristic promptness and scientific precision.

Prof. F. H. Knowlton, assistant curator of botany and fossil plants of the National Museum, has become deeply interested in the subject of the internal structure of fossil wood, lignite, etc., and has within the last year entered actively upon its study. As I reported a year ago, he accompanied the second of the field expeditions made during that year to the plant beds of the Potomac and James rivers and collected material of that class at all the points visited. Other collections that have been made in the vicinity of Washington and Baltimore have been placed in his hands. As he is an expert with the microscope and uses his own instrument, but needed some accessories for this work, I secured the purchase of the latter by the U. S. Geological Survey. The National Museum has also co-operated in this matter by fitting up a special room with suitable tables, drawers, and apparatus.

In November Professor Knowlton was ready to begin work, and he prepared a number of slides during the early part of the winter. In April he set about preparing a paper on the fossil wood and lignite of the Potomac formation, and it was completed and submitted for publication as a bulletin on the 20th of June. The paper possesses especial interest in view both of the little that has been done and of the great amount that should be done in America in this important branch of paleontology.

Since January 1 I have found intervals of time in which to resume work on the introductory part of the monograph which is to deal with some of the more general questions presented by paleobotany. The paper in the Fifth Annual Report of the Survey entitled "Sketch of Paleobotany" forms the first part of this discussion and treats of the historical development of the science. I have now compiled most of the data for a review of the more recent progress in the discovery of fossil plants in different countries, and especially in the United States, and also for the analysis of many of the general results already arrived at as bearing upon geologic succession, changes of climate, and the evolution of types of vegetation.

The facts of geographical distribution seemed of primary importance, and I have made this the subject of a special paper, which I herewith submit for publication in the Eighth Annual Report.

WORK OF PROFESSOR FONTAINE.

Prof. William M. Fontaine submits the following report of work done by him during the fiscal year:

"In company with Prof. Lester F. Ward I made an examination

during the summer of the Potomac formation as shown on the banks of the Potomac river below Washington and along the James river below Richmond. The character and the distribution of the formation were determined and large collections of the fossils were made.

"After this, I re-examined a number of points between Washington and Baltimore, in order that the relations of the two members of the Potomac formation might be determined. I succeeded in finding at Baltimore a new locality yielding fossil plants. From this a considerable and important collection of fossils has been made.

"During the rest of the time I have been occupied in the preparation of the material collected for publication. This additional material has delayed my report on the Potomac flora, since it was important that it should be included. The report is now completed, and will soon be forwarded.

"I shall proceed immediately to put my report on the geology of the Potomac formation in shape for the printer, and hope to have it ready very soon."

Very respectfully, your obedient servant,

LESTER F. WARD,
Geologist in Charge.

Hon. J. W. POWELL,
Director U. S. Geological Survey, Washington, D. C.

REPORT OF MR. SAMUEL H. SCUDDER.

DEPARTMENT OF THE INTERIOR,
U. S. GEOLOGICAL SURVEY,
DIVISION OF FOSSIL INSECTS,
Cambridge, Mass., July 1, 1887.

SIR: During the last year considerable progress has been made in the study of the Tertiary Coleoptera of this country, six families being now almost completely worked up, while some time has been given to a seventh. The Tertiary fauna of North America in these families now includes 56 species of 23 genera of Carabidæ—almost as many as are found in Europe; 2 species of distinct genera of Dytiscidæ; 17 species of 9 genera of Hydrophilidæ; 2 species of as many genera of Silphidæ; 47 species of 25 genera of Staphylinidæ—nearly doubling the previously known Tertiary species in this family; and 2 species of 2 genera of Coccinellidæ. The remaining Clavicornia are now under investigation. Only two new generic types occur, one in the Carabidæ and one in the Staphylinidæ.

There has also been prepared and forwarded for the present report a paper on the butterflies of the Tertiary deposits of this country, the very rarest of fossil insects, of which 7 species are described and figured, including some of unusual interest. Nine are known from the Old World.

Mr. J. H. Blake has continued his drawings of fossil insects, com-

pleting the first series of the Diptera which had been laid out, having made 18 drawings of Mycetophilidæ, 48 of Tipulidæ, and 10 of Culicidæ and other smaller Nematocera. He has also drawn 32 Coleoptera, of which 22 are Staphylinidæ and 10 belong to various families; besides 15 Lepidoptera for the paper on fossil butterflies. He has recently commenced work on the Hymenoptera, and has already completed 25 drawings.

Bulletin 31, containing a general review of our present knowledge of fossil insects, was published during the year; it gives under each family of insects a summary of the known fossil species, systematically arranged, with most of the genera of the older rocks briefly defined.

Respectfully submitted.

SAMUEL H. SCUDDER,
Paleontologist in Charge.

Hon. J. W. POWELL,
Director U. S. Geological Survey, Washington, D. C.

REPORT OF PROF. F. W. CLARKE.

DEPARTMENT OF THE INTERIOR,
U. S. GEOLOGICAL SURVEY,
DIVISION OF CHEMISTRY AND PHYSICS,
Washington, D. C., July 1, 1887.

SIR: I have the honor to submit the following report, covering the work of this division for the fiscal year 1886–'87.

In the organization and policy of the division there has been no change from previous years, except that the personnel has suffered by the loss of Dr. F. A. Gooch, who left the Survey on July 1, 1886, to accept the chair of chemistry in Yale College. During the year the work of the chemical laboratory has been carried on by Messrs. Hillebrand, Chatard, Whitfield, Riggs, and myself, and the physical researches have, as heretofore, been in the hands of Messrs. Barus and Hallock.

In the main, the results of the year's labors have been quite satisfactory. Three hundred and thirty-five analyses, great and small, have been made and reported, of which a fair number represented scientific investigations to be noted further on. Of the purely routine work the following series of analyses may be cited as important:

(1) Fifteen rocks, collected by Mr. J. S. Diller in California.

(2) Thirty-four rocks, collected by Prof. R. D. Irving in Wisconsin and Minnesota.

(3) Fifteen rocks and thirty-four waters, sediments, incrustations, etc., collected by Mr. Arnold Hague in the Yellowstone Park.

(4) Seventeen clays etc. collected by Prof. N. S. Shaler at Gay Head, Martha's Vineyard, Mass.

(5) Forty-nine assays for precious metals, eleven iron ore analyses, and seven analyses of coals.

(6) Eighteen waters from various springs, artesian wells, lakes, etc.

(7) Two samples of steel for the U. S. A. Ordnance Bureau, and one building stone for the Supervising Architect of the Treasury.

In the pursuit of our various investigations upon mineralogical chemistry we have had most gratifying co-operation from a number of individuals. Valuable material has been contributed by Mr. N. H. Perry, of South Paris, Me.; Prof. C. H. Hitchcock, of Dartmouth College; Mr. G. F. Kunz, of New York; Mr. William Earl Hidden, of Newark, N. J.; Mr. C. S. Bement, of Philadelphia; Mr. Richard Pearce, of Denver, and others. Prof. E. S. Dana, of New Haven, has also kindly assisted us with certain crystallographic determinations. I take pleasure in citing these names, partly as a slight acknowledgment of courtesies received and partly as evidence of a widespread interest in our work.

Throughout the year I have continued my investigations regarding the chemical structure of the natural silicates, and in April I practically completed that portion of it which relates to the mica group. Certain new relations connecting the members of that group and explaining several apparent anomalies will appear in our next bulletin. Since the middle of April I have been at work upon jade and jadite, acting in co-operation with Mr. George P. Merrill, of the U. S. National Museum, and our joint research will probably be finished early next winter. In August and September I was absent for five weeks upon a field collecting trip, during which I visited mineral localities in Raymond, Windham, and Andover, Me., and the emery mine at Chester, Mass. At each of these points I secured valuable material for study.

Mr. W. F. Hillebrand, in addition to some work upon analytical methods, examined and described a number of rare minerals. Among them were the exceedingly rare species mixite, clinoclasite, erinite, and tyrolite from the Tintic district, Utah, minerals never before found in America; jarosite, from Colorado; white beryl, from Winslow, Me., and a columbo-tantalate near samarskite in character. He also analyzed two other minerals which are problably new: one a sulphide of zinc, silver, and copper from Montana, the other a basic copper sulphate from the Antler mine, Arizona.

Several interesting researches have been finished by Mr. J. Edward Whitfield. First, an investigation of the geyser waters of the Yellowstone Park, begun in combination with Dr. F. A. Gooch, was pushed to completion. These waters have great interest, not only from the geological point of view, but also therapeutically, for most of them carry determinable quantities of boric acid and of arsenic. This research, bearing the names of Gooch and Whitfield as joint authors, has been put in the form of a separate bulletin and has been handed in for publication. I do not exaggerate when I say that it

is one of the most complete studies of the kind on record. Mr. Whitfield has analyzed and described two new meteoric irons, one from Johnson county, Ark., and one from Allen county, Ky., and a series of natural borates and borosilicates. The latter analyses were made for the purpose of fixing the true composition of the several minerals, and cover the species colemanite, priceite, pandermite, ulexite, ludwigite, datolite, danburite, and axinite.

Among the minerals which are widely diffused in a great variety of rocks tourmaline is one of the commonest. It is, however, quite complex in composition, and its complete analysis is attended by so many difficulties that its true formula has been heretofore unknown. This point has now been cleared up by Mr. R. B. Riggs, who made most thorough analyses of about twenty samples of tourmaline, covering nearly all of its varieties, several modes of occurrence, and a goodly number of different localities. He has also studied a number of the alterations and associates of tourmaline, making in all an investigation of the most complete character. This research, together with several of the investigations previously mentioned, will appear in the next laboratory bulletin.

By Dr. T. M. Chatard an investigation of a totally different character has been pushed forward. Two years ago he began a careful study of the saline and alkaline minerals of the United States, and in the Seventh Annual Report of the U. S. Geological Survey, 1885–'86, will be found some account of his work in the salt producing regions of New York, Michigan, and West Virginia. This year his work was transferred to the far West, and the following outline will serve to indicate its character:

Leaving Washington on August 6, 1886, Mr. Chatard went, via Carson, Nev., to Mono lake, in California, and through the Long valley country. At Mono lake he made arrangements for securing samples of the brine, which is rich in carbonate of soda; and in Long valley, which drains through Owen's river into Owen's lake, he made some preliminary examinations, leaving detailed study for another field season. He next went to Owen's lake, which, having railroad communication with Carson, is most favorably situated for the growth of chemical industry. Here the commercial development of the soda manufacture has actually begun, and Mr. Chatard spent about three weeks in studying the work and its conditions. He made a systematic series of experiments upon the rapidity of solar evaporation, and also carried out a set of fractional crystallizations of the salts contained in the lake water. The successive crops of crystals, together with samples of both the natural and the concentrated water, were sent to the Washington laboratory for further study. From Owen's lake Mr. Chatard went to Rhodes's marsh, Nevada, where there are extensive salt marshes and borax works, and on his homeward journey he visited some of the salt makers at Great Salt lake.

At each of these points he secured valuable information and found men who were ready to co-operate with him most cordially. He returned to Washington in October, and during the winter a considerable portion of his time was devoted to the analysis of the samples of waters and salts collected and to the repetition of field experiments upon a laboratory scale. He has also begun the collection of data concerning the distribution of nitre deposits in the United States, and in the coming field season he hopes to visit new localities and to continue upon a larger scale the work already started at Owen's and Great Salt lakes. All of these investigations have both practical and scientific bearings and should be vigorously pushed. Their economic importance is beyond question.

In the physical laboratory, Dr. Carl Barus, continuing his studies of the iron carburets, has investigated their viscosity and that of metals generally in relation to hardness. He has also considered the relations of viscosity for metals and for glass to temperature and the effect of magnetization upon the viscosity of iron and steel. In these researches he has devised new and sensitive methods for studying changes in either rigidity or viscosity, no matter how produced. In continuation of his work upon the measurement of high temperatures, he has made a general survey of the pyrometric properties of over fifty alloys of platinum, determining such constants as density, resistance, thermo-electric power, and temperature co-efficients. A thermo-electric study of the constancy of temperature attainable in **W** crucibles was also made and their availability for calibration of temperatures and boiling point measurements was determined as far as the boiling point of tin. He furthermore conducted experiments upon the air thermometry of high temperatures and on methods of soldering and welding porcelain in the oxyhydrogen furnace; and he now purposes the construction of a fire clay air thermometer suitable for withstanding very great heat. By means of a revolving muffle he has secured constancy of temperatures at points far above that at which porcelain becomes viscous, and he designs this apparatus for use in the calibration of thermo-elements. Finally he has designed apparatus for the absolute measurement of pressure, especially intended for use in researehes upon the relations between pressure and melting point. A manuscript detailing the results so far obtained in the high temperature work will soon be ready for publication.

During the late summer and early autumn of 1886 Mr. Hallock was detailed for duty in the Yellowstone Park. He there assisted Mr. Hague in continuing the study of the geyser phenomena, especially as regards temperature; and he also made observations upon evaporation, precipitation, and the rate and amount of flow in various rivers and creeks. In November he returned to the laboratory and began an investigation of the co-efficients of expansion of rocks and minerals. In addition he rendered some assistance to other divisions of the Sur-

vey in matters of seismometry, and he has made a valuable series of determinations upon the specific gravity of jadite and jade. His main problem, however, to be pushed most vigorously in the future, is that of expansion.

Very respectfully,

F. W. CLARKE,
Chief Chemist.

J. W. POWELL,
Director U. S. Geological Survey, Washington, D. C.

REPORT OF MR. J. S. DILLER.

DEPARTMENT OF THE INTERIOR,
U. S. GEOLOGICAL SURVEY,
DIVISION OF PETROGRAPHY,
Washington, D. C., July 1, 1887.

Sir: Herewith I have the honor to submit a report of work performed under my direction in the petrographic laboratory during the year ending June 30, 1887.

This work required only a small portion of my attention, the larger part of my time being devoted, under the direction of Capt. C. E. Dutton, to investigations in the geology of northern California.

The operations in the laboratory are of two kinds: (1) The preparation of material for research and (2) the study of specimens submitted for investigation. The value of special petrographic investigations as an aid in geologic research is now fully recognized, and the preparation of material for that purpose has become an important part of the laboratory work. Thin sections of rocks were first made in this laboratory during the autumn of 1883. One skilled workman was employed and the grinding was entirely by hand. This primitive method was soon superseded by the use of lathes, which have recently been greatly modified and improved. At present three skilled workmen are continuously engaged at this work. Three cast iron lathes run by steam are used, and, by the employment of a holder, so that thirty sections may be ground at the same time, the quantity of work done is greatly increased.

The amount of grinding actually required is reduced to a minimum by cutting off thin slices of the rock to be ground. The saw lately made for this purpose, according to a plan suggested by one of my assistants, Hermann Ohm, is a great improvement upon the expensive diamond saw formerly employed. It consists essentially of an iron wire fed with emery and run in a vertical plane as a belt about two pulleys, one of which is connected with the power and the other is adjustable. In this way much larger specimens can be cut than by using a diamond saw, and they can be cut to any desired shape. It

furnishes a most valuable aid in the preparation of cut and polished specimens to illustrate peculiar structural features of fossils and rocks. During the year nearly four thousand thin sections of rocks have been made for the Survey and one hundred specimens of various sizes have been cut and polished.

Over one hundred specimens were submitted to the laboratory chiefly by individuals not connected with the Survey, some for determination and others for special study. Among the former may be mentioned paving and building stones used in Washington, a small collection of rocks for Brown University, and a series of serpentines from near Quincy, Plumas county, Cal.

Prof. C. H. Hitchcock submitted a suite of rocks for study. The collection was made by him for the purpose of illustrating the structure and determining the origin of Mt. Ascutney, Vermont. It has been studied with care and lends support to the view which regards the mountain as the result of a massive eruption.

The optical properties of a number of micas and other minerals were determined for Prof. F. W. Clarke, who made an extensive series of chemical investigations upon the same material.

The recent advances in our knowledge of the development of crystallization in eruptive rocks render it desirable to examine the collection of rocks from the laccolites of the Henry mountains with especial reference to this feature. The investigation has already commenced and promises to yield interesting results.

During the year two papers have been published containing the results of laboratory work, one upon "The latest volcanic eruption in Northern California and its peculiar lava," in the American Journal of Science, 3d ser., Vol. XXXIII, p. 45, 1887, and the other on The Peridotite of Elliott County, Kentucky, U. S. Geological Survey Bulletin No. 38. The latter has attracted attention from the fact that the peridotite is almost identical with that of the diamond mines of South Africa, and the probability of finding diamonds in Kentucky was at once suggested. The carbonaceous shale adjoining the peridotite in Kentucky is so much poorer in carbon than that at the Kimberley and other South African mines as not to excite much enthusiasm in searching for diamonds at this locality. Mr. George F. Kunz, a gem expert, and myself have carefully examined in the field the Kentucky peridotite, as well as its residuary deposits, but we failed to find convincing evidence of the presence of diamonds.

I have the honor to be,

Very respectfully, your obedient servant,

J. S. DILLER,

Assistant Geologist in Charge.

Hon. J. W. POWELL,

Director U. S. Geological Survey, Washington, D. C.

REPORT OF MR. DAVID T. DAY.

DEPARTMENT OF THE INTERIOR,
U. S. GEOLOGICAL SURVEY,
DIVISION OF MINING STATISTICS AND TECHNOLOGY,
Washington, July 1, 1887.

SIR: In submitting an account of the operations of the division of mining statistics and technology for the fiscal year ending June 30, 1887, I have the honor to report that, aside from the correspondence arising from requests for technological information, attention has been devoted chiefly to the economic consideration of the minerals of the United States. This involved the preparation of two reports, the third and fourth of the series called Mineral Resources of the United States. At the beginning of the fiscal year 1887 the material for the third of these reports, which bore the title "Mineral Resources of the United States, 1885," had been gathered and was undergoing editorial revision. On September 15, the report was transmitted to the Government Printing Office. On September 1, a plan was submitted for a similar report, to be called "Mineral Resources of the United States, 1886." From that date to the end of the following January the work of the division consisted in proof revision of the report for 1885 and in the preparation of the report to succeed it. On January 29, 1887, the report for 1885 was received from the Public Printer. Since that date 469 copies have been sold at the cost of publication, 40 cents; 741 copies have been sent in exchange for other publications and 1,050 in return for information received in the compilation of the report. February, March, and April of 1887 were devoted to collecting the statistics for the calendar year that closed December 31, 1886. At this date the reports, about seventy in number, constituting the different chapters of the book have been received, and they will be transmitted to the Public Printer at once.

Among the facts presented in this report the following are worthy of especial attention:

Notably increased production and also an increase in value have been the general characteristics of the mineral industries during 1886. The total value of the mineral products increased in round numbers from $428,700,000 in 1885 to $465,300,000 in 1886. If the total quantities of minerals produced in the two years could be compared, the increase would be even more striking. The important factor in this gain of $36,600,000 was the increased production of pig iron from 4,044,525 long tons in 1885 to 5,683,329 long tons in 1886, with an appreciation of 75 cents in the average value per ton, making a total gain of $30,483,360 in this industry alone.

The condition of the individual industries is summarized below:

METALS.

Iron.—The principal statistics for 1886 were: Domestic iron ore consumed, 10,000,000 long tons; value at mines, $28,000,000. Imported iron ore consumed, 1,039,433 long tons; total iron ore consumed, 11,039,433 long tons. Pig iron made, 5,683,329 long tons, an increase of 1,638,804 tons as compared with 1885; value at furnace, $95,195,760, or $30,483,360 more than in 1885. Total spot value of all iron and steel in the first stage of manufacture, excluding all duplications, $142,500,000, an increase of $49,500,000 as compared with 1885.

Gold and silver.—The total value of gold produced in 1886 was $35,000,000, an increase of $3,199,000 over 1885. The production of silver decreased from $51,600,000 in 1885 to $51,000,000 in 1886.

Copper.—The production in the year 1886, including 4,500,000 pounds from imported pyrites, amounted to 161,235,381 pounds, valued at $16,527,651, a decrease of 9,727,226 pounds and $1,765,348 in value from 1885. The average price of copper in 1886 declined to 10¼ cents per pound. The copper sulphate, made chiefly from ores and matte, amounted to 13,400,000 pounds, valued at $536,000, at 4 cents per pound.

Lead.—The total production increased to 135,629 short tons in 1886, valued at $12,667,749, at an average price of $93.40 per ton in New York. In 1885 the production was 129,412 tons, valued at $10,469,431. The production of white lead in 1886 is estimated at 60,000 short tons, worth, at 6¼ cents per pound, $7,500,000. The total value of the oxides of lead was about $1,535,000.

Zinc.—Production, 42,641 short tons; value, $3,752,408 at $88 per short ton, an increase of 1,953 short tons in quantity and of $212,552 in value over 1885. There are preparations for a further increase during 1887. Zinc oxide (zinc white) was also made directly from ores to the amount of 18,000 short tons, valued at $1,440,000.

Quicksilver.—In 1886 the production in California was 29,981 flasks, or 2,291,547 pounds, valued at $1,060,000. This is a decrease of 2,092 flasks, but the total value shows an increase of $80,811, due to an increase to $35.35 in the price per flask. Utah produced 87 flasks of quicksilver in addition to the above. The production of quicksilver vermilion increased to 700,000 pounds and its value to $392,000 owing to the increase in price of quicksilver.

Nickel.—The production amounted to 214,992 pounds, including 182,345 pounds of metallic nickel and the metallic nickel in 122 tons of nickel and cobalt matte, in 35 tons of exported ore, and in 46,138 pounds of nickel ammonium sulphate; total value, $127,157.

Cobalt.—In addition to 8,689 pounds of cobalt oxide at $2 per pound, ore and matte were produced, making the total value $36,878.

Chromium.—The production of chrome iron ore decreased. In 1886 about 2,000 long tons were sold, all from California, where its total value was $30,000.

Manganese.—The production of manganese ores was 30,193 long tons, valued at $277,636. In addition to this, 257,000 tons of iron ore, with from 2 to 4 per cent. of manganese in the same, were produced, and 60,000 tons of manganiferous ores, containing from 4 to 20 per cent. of manganese, that were used as fluxes in the silver region. The production of manganese ores in 1885 was 23,258 long tons, valued at $190,281.

Tin.—Development work in the Black Hills resulted in the accumulation of considerable ore piles at the mines awaiting concentration.

Antimony.—Production, 35 tons metallic antimony, valued at $7,000. A small amount of sulphide of antimony was also sold for chemical manufacture.

Aluminum.—Aluminum bronze containing 10 per cent. aluminum was made to the extent of 50,000 pounds, valued at $20,000, at 40 cents per pound. About 2,500 pounds of iron alloy, containing 6 to 8 per cent. aluminum, was also sold for $7,000.

Platinum and iridium.—The production of platinum sand was only 50 troy ounces, valued at $100. About 300 ounces of domestic iridosmine for pen points was sold in 1886 for $1,000.

FUELS.

Coal.—The total production of all kinds of coal in 1886, exclusive of that consumed at the mines, known as colliery consumption, was 107,682,209 short tons, valued at $147,112,755 at the mines. This may be divided into Pennsylvania anthracite 36,696,475 short tons, or 32,764,710 long tons, valued at $71,558,126 ; all other coals, including bituminous, brown coal, lignite, and small lots of anthracite produced in Rhode Island, Arkansas, and Colorado, 70,985,734 short tons, valued at $75,554,629. The colliery consumption at the individual mines varies from nothing to 8 per cent. of the total product, being greatest at special Pennsylvania anthracite mines and lowest at those bituminous mines where the bed is nearly horizontal and where no steam power or ventilating furnaces are employed. The averages of the different States vary from 3 to 6 per cent., the latter being the average in the Pennsylvania anthracite region.

The total production, including colliery consumption, was : Pennsylvania anthracite, 34,853,077 long or 39,035,446 short tons, all other coals, 65,810,676 long tons or 73,707,957 short tons; making the total absolute production of all coals in the United States 112,743,403 short tons, valued as follows : Anthracite, $76,119,120 ; bituminous, $78,481,056 ; total value, $154,600,176. The total production of Pennsylvania anthracite, including colliery consumption, was 699,473

short tons in excess of that produced in 1885, but its value was $552,828 less. The total production of bituminous coal was 1,086,408 short tons greater than in 1885, while its value was $3,866,592 less. The total production of all kinds of coal shows a net gain of 1,785,881 short tons compared with 1885, but a loss in spot value of $4,419,420.

Coke.—The total production of coke in 1886 was 6,835,068 short tons, valued at the ovens at $11,552,781. This is the largest production ever reached in the United States, the nearest approach to it being in 1883, when 5,464,721 tons were made. This declined in 1884 to 4,873,805 tons. The year 1885 showed a gain upon 1884, the total being 5,106,696 tons. The production for 1886 shows a gain on that of 1885 of 1,728,372 tons, or nearly 34 per cent. The total increase in value was $3,923,663. The production of 1886 is 1,370,347 tons, or nearly 25 per cent. greater than the maximum of previous years.

Petroleum.—The total production was 28,110,115 barrels of 42 gallons each, of which the Pennsylvania and New York fields produced 25,798,000 barrels. The total value, at 71¼ cents a barrel, the average value of the Pennsylvania and New York petroleum, was $20,028,457. The production showed an increase of 6,268,074 barrels over the production of 1885.

Natural gas.—No record is kept of the yield in cubic feet. It is estimated that the amount of coal for which natural gas was substituted in 1886 was 6,353,000 tons, valued at $9,847,150. In the year 1885 the corresponding amount of coal was 3,161,600 tons, valued at $4, 854,200.

STRUCTURAL MATERIALS.

Building stone.—Value estimated to be about the same as in 1885, $19,000,000.

Brick and tile.—Value, $38,500,000; this value represents an increase of 10 per cent. over last year. The increase in production was slightly greater than 10 per cent. There was some falling off in value during a part of the year.

Lime.—The production is estimated at 42,500,000 barrels, with an average value of 50 cents per barrel.

Cement.—Production of cement from natural rock was 4,350,000 barrels, valued at $3,697,500; artificial Portland cement, about the same as last year, 150,000 barrels, valued at $292,500. The total production of cement of all kinds was 4,500,000 barrels, valued at $3,990,000.

Buhrstones.—The total value of the finished buhrstones was $275,000. The increased use of roller mills affected the French buhrstones more than the domestic stones.

Grindstones.—Total value, $250,000; produced mainly in Ohio and Michigan.

Corundum.—The production in the past few years has been quite steady; in 1886 it was 645 short tons, valued at $116,190.

Novaculite.—The rough whetstones amounted to 1,160,000 pounds, valued at $15,000. The value of the stones is greatly increased by cutting.

Infusorial earth.—The production for the year amounted to 1,200 short tons, with a spot value of $6,000, all from Maryland.

Flint.—About 30,000 long tons, having a spot value of $120,000, were used in pottery manufacture, besides a considerable amount for sandpaper.

MISCELLANEOUS.

Precious stones.—The value of the rough gems sold in 1886 was $79,056. In addition, gold quartz was sold for specimens and for gems to the value of $40,000. The value of this, when polished, is $100,000.

Phosphate rock.—Total production was 430,549 long tons, all from South Carolina, except experimental lots from Alabama, Mississippi, and Florida. The total value was $1,872,936. The production decreased 7,307 long tons and the value $973,128 from 1885.

Marls.—The main production is from New Jersey, and is comparatively steady at 800,000 short tons, valued at $400,000. Considerable local use is also made of many small deposits in North and South Carolina, Alabama, Mississippi, and Florida.

Salt.—The total production increased from 7,038,653 barrels (of 280 pounds each) in 1885 to 7,707,081 barrels in 1886. The total value, however, decreased slightly: in 1886 it was $4,736,585, and in 1885, $4,825,345.

Bromine.—Both the production and the average price of bromine increased markedly in 1886. The total production was 428,334 pounds in 1886 and 310,000 in 1885. The total value in 1886 was $141,350, and in 1885, $89,900.

Phosphorus.—Production, 30,000 pounds, valued at $20,000.

Borax.—Production, 9,778,290 pounds, all from California and Nevada. Total value, $488,915, at 5 cents per pound for concentrated.

Sulphur.—The production amounted to 2,500 short tons, valued at $75,000.

Pyrites.—About 55,000 long tons were produced, valued at $247,500, at $4.50 per long ton, at the mines. In addition, 57,000 tons were imported.

Barytes.—Estimated production, 10,000 long tons of crude, valued at $50,000.

Gypsum.—Estimated total production of crude gypsum was 95,250 short tons, valued at $428,625. From this 50,000 short tons of land plaster and 26,000 short tons of calcined plaster were made. In addition, 122,270 tons of crude gypsum were imported, chiefly from Nova Scotia.

Mica.—The production has decreased to 40,0 0 pounds, valued at $70,000. This is exclusive of 1,000 tons of waste, valued at $10,000.

Feldspar.—Production, 14,900 long tons, valued at $74,500, at $5 per ton for the crude unground material. This is an increase of 1,300 tons over 1885. The price has remained constant.

Asbestus.—The domestic production was about 200 short tons, valued at $30 per ton at the mines. The production is decreasing, owing to importation of a better quality from Canada.

Asphaltum.—The production increased to 3,500 tons, valued at $14,000 at the deposits in California. In 1885 the value was $10,500.

Ochre.—Production, including metallic paint, umber, and sienna, 15,800 short tons, valued at $285,000.

Graphite.—The production in 1886 was 415,525 pounds, valued at $33,242. In 1885 the production was 327,883 pounds, valued at $26,230. The price remained constant at 8 cents per pound. This is exclusive of 500 tons of impure graphite mined at Cranston, R. I., for metallurgical purposes.

Alum.—Production, 90,000,000 pounds, valued at $1,350,000. About three-fourths is made from imported cryolite, beauxite, aluminous shale, and other raw materials.

Copperas.—Production, 22,000,000 pounds, or 11,000 short tons; value, at 50 cents per hundred weight, $110,000.

Fluorspar.—The annual production for the past three years has been about 5,000 tons, valued at the mines in Indiana at $4.50 per ton, or $22,500.

Rutile.—Production, for coloring artificial teeth, about 600 pounds, valued at $2,000.

Mineral waters.—Considering only the amount sold, the production was 8,950,317 gallons, valued at $1,284,070. This shows a slight total decrease since 1885. This may be only apparent. If all the springs had reported, the figures would probably have shown a total increase, although some large springs undoubtedly sold less.

Lithographic stones.—Considerable effort is being made to develop the industry in Tennessee and Kentucky. About 50 tons have been taken out and dressed. The use of the stones has proved quite satisfactory and will probably increase.

Magnesite.—Heretofore the raw materials for making magnesium compounds have been imported, chiefly from Germany. The annual imports of magnesite vary from 100,000 to 2,000,000 pounds. In 1886 the production of magnesite was begun on Cedar mountain, Alameda county, Cal. The product, amounting to several tons, was shipped to New York.

On September 1, Mr. Albert Williams, jr., chief of this division, tendered his resignation, and was subsequently designated a non-resident geologist; he has since given valuable assistance in revising

proof sheets and suggesting profitable lines of work. On his resignation the undersigned was appointed geologist in charge. Besides myself, the office force consisted during the year of Mr. William A. Raborg and Mr. Jefferson Middleton, who, with occasional additional assistants, gave valuable and intelligent aid in conducting the work of the office.

Very respectfully, your obedient servant,

DAVID T. DAY,
Geologist in Charge.

Hon. J. W. POWELL,
Director U. S. Geological Survey, Washington, D. C.

REPORT OF MR. GEORGE W. SHUTT.

DEPARTMENT OF THE INTERIOR,
U. S. GEOLOGICAL SURVEY,
DIVISION OF FORESTRY,
Washington, D. C., July 1, 1887.

SIR: In addition to the general business duties pertaining to my position as general assistant, investigation in regard to the forest growth of our States and Territories, as chief of the forestry division, has been diligently prosecuted, and returns of a satisfactory character through selected correspondents have been received from a majority of the counties of the States east of the Rocky Mountains. In the States correspondents have been selected in each county. The returns from the South are more general than from other parts of the United States. Sufficient information has been secured to enable me to localize the different genera and species with approximate accuracy. I have also been enabled to indicate the localities suitable for the reproduction of forest valuable to commerce and to show where existing forests have not yet been utilized.

I am making my report by counties, depending for its accuracy partly upon personal inspection and partly upon the information received from correspondents. There is little doubt that knowledge sufficiently accurate for all practical and scientific purposes in regard to the forest growth of this country will soon be acquired by the method adopted, the cost of which is comparatively small since the gentlemen from whom I receive reports do not require compensation. The information thus received is, in my judgment, of great importance.

The time is at hand when accurate knowledge of our forest resources and our capacity for spontaneous and artificial reproduction must be secured, so that proper legislative action may be had to preserve and perpetuate forest products in view of the manifold industries dependent upon them.

The field expenses of the year have been small, and personal inspection of localities, except in the State of Virginia, has been limited, other duties connected with my position having detained me in Washington or in the immediate neighborhood.

I have prepared a report of a general character in regard to the forest products, their capacity, their annual consumption by commerce, their approximate absorption by the encroachments of agriculture, their destruction by fire, etc., the publication of which is respectfully requested, and I also have in course of preparation a report by counties in the States and by the smallest subdivisions in the Territories, which will be completed as to each State and Territory as the returns are received.

Very respectfully, your obedient servant,

GEORGE W. SHUTT,
General Assistant, U. S. Geological Survey.

Hon. J. W. POWELL,
Director U. S. Geological Survey, Washington, D. C.

REPORT OF MR. W. H. HOLMES.

DEPARTMENT OF THE INTERIOR,
U. S. GEOLOGICAL SURVEY,
DIVISION OF ILLUSTRATIONS,
Washington, D. C., July 1, 1887.

SIR: During the last year the work of preparing illustrations for the various publications of the Survey has been conducted in the usual manner and without change in the personnel of the division.

One annual report and seven bulletins have been transmitted through this office, and the illustrations accompanying them, exclusive of maps and charts, may be classed as follows:

Five plates by chromolithography.
Five plates by lithography.
Twenty-nine plates by wood engraving.
Forty-nine plates by photo-engraving.
Ten plates by photolithography.
One plate by engraving on stone.
Sixty-one figures by wood engraving.
Seventy-six figures by photo-engraving.

The following list shows approximately the drawings executed since June 30, 1886:

Fossil mollusca, 402 figures.
Fossil vertebrates, 40 plates and 150 figures.
Fossil insects, 148 figures.
Fossil plants, 470 figures.
Mineralogical specimens, 50 figures.
Geological landscapes, 53 plates and figures.
Sections and diagrams, 80 plates and figures.

The photographic work, in charge of Mr. J. K. Hillers, has been carried on without important change. No systematic field work has

been undertaken, the whole force finding employment in the laboratory. The work, as heretofore, consisted chiefly in the copying and printing of topographic maps and paleontologic and mineralogic specimens, and in the printing of negatives of various classes for use by the collaborators of the Survey.

A number of the geologic and topographic parties were supplied with photographic outfits and many negatives of importance were thus added to the collection. The following is a list of the negatives, prints, and transparencies made during the year:

Negatives.		Prints.		Transparencies.	
Size (in inches).	Number.	Size (in inches).	Number.	Size (in inches).	Number.
28 x 34	184	28 x 34	1,063	28 x 34	49
20 x 24	254	20 x 24	1,714	20 x 24	26
14 x 17	24	14 x 17	81		
11 x 14	122	11 x 14	5,615		
8 x 10	176	8 x 10	1,220		
5 x 8	153	5 x 8	1,459		

Very respectfully, your obedient servant,

W. H. HOLMES,
Geologist in Charge.

HON. J. W. POWELL,
Director U. S. Geological Survey, Washington, D. C.

REPORT OF MR. CHARLES C. DARWIN.

DEPARTMENT OF THE INTERIOR,
U. S. GEOLOGICAL SURVEY,
DIVISION OF THE LIBRARY AND DOCUMENTS,
Washington, D. C., July 1, 1887.

SIR: I have the honor to submit the following statement of work done in this division during the fiscal year ended June 30, 1887:

LIBRARY.

The library has outgrown its present storing capacity, and all available shelving space is occupied by those books which are continually used. Confusion has been so far prevented and facility of reference secured by shelving all duplicate sets of transactions of societies in one of the rooms for storage of documents. The library is now distributed through four widely separated rooms: the main library room, a room on the first and one on the third floor, occupied last year, and the new storage room in the basement.

Contents of the library, June 30, 1887.

BOOKS.

On hand June 30, 1886:			
Received by exchange	12,718		
Received by purchase	4,537		
		17,255	
Received during the year:			
By exchange	1,973		
By purchase	273		
		2,246	
			19,501

PAMPHLETS.

On hand June 30, 1886:			
Received by exchange	18,400		
Received by purchase	1,200		
		19,600	
Received during the year:			
By exchange	6,250		
By purchase	250		
		6,500	
			26,100
Total number of books and pamphlets			45,601

All the book accessions of the year have been properly catalogued and shelved, and a beginning has been made in preparing cards for the scientific papers published in society memoirs and transactions. Any great progress, however, in such card indexing has been prevented by the many demands of general library work. More books were used than ever, and the average of last year of 1,000 books drawn and returned every month has been this year greatly exceeded.

PUBLICATIONS.

The Sixth Annual Report, Monographs X and XI, Bulletins Nos. 27 to 39, and the third volume of Mineral Resources have been published during the year, making the list of the publications of the Survey now issued as follows:

ANNUAL REPORTS.

I. First Annual Report of the United States Geological Survey to the Hon. Carl Schurz, by Clarence King. 1880. 8°. 79 pp. and 1 map.—A preliminary report describing plan of organization and publications.

II. Second Annual Report of the United States Geological Survey, 1880–'81, by J. W. Powell. 1882. 8°. lv, 588 pp. 61 pl. and 1 map.

III. Third Annual Report of the United States Geological Survey, 1881–'82, by J. W. Powell. 1883. 8°. xviii, 564 pp. 67 pl. and maps.

IV. Fourth Annual Report of the United States Geological Survey, 1882–'83, by J. W. Powell. 1884. 8°. xxxii, 473 pp. 85 pl. and maps.

V. Fifth Annual Report of the United States Geological Survey, 1883–'84, by J. W. Powell. 1885. 8°. xxxvi, 469 pp. 58 pl. and maps.

VI. Sixth Annual Report of the United States Geological Survey, 1884–'85, by J. W. Powell. 1886. 8°. xxix, 570 pp. 65 pl. and maps.

MONOGRAPHS.

II. Tertiary History of the Grand Cañon District, with atlas, by Clarence E. Dutton, Capt. U. S. A. 1882. 4°. xiv, 264 pp. 42 pl. and atlas of 24 sheets folio. Price $10.12.

III. Geology of the Comstock Lode and the Washoe District, with atlas, by George F. Becker. 1882. 4°. xv, 422 pp. 7 pl. and atlas of 21 sheets folio. Price $11.

IV. Comstock Mining and Miners, by Eliot Lord. 1883. 4°. xiv, 451 pp. 3 pl. Price $1.50.

V. Copper-Bearing Rocks of Lake Superior, by Roland D. Irving. 1883. 4°. xvi, 464 pp. 15 l. 29 pl. Price $1.85.

VI. Contributions to the Knowledge of the Older Mesozoic Flora of Virginia, by Wm. M. Fontaine. 1883. 4°. xi, 144 pp. 54 l. 54 pl. Price $1.05.

VII. Silver-Lead Deposits of Eureka, Nevada, by Joseph S. Curtis. 1884. 4°. xiii, 200 pp. 16 pl. Price $1.20.

VIII. Paleontology of the Eureka District, by Charles D. Walcott. 1884. 4°. xiii, 298 pp. 24 l. 24 pl. Price $1.10.

IX. Brachiopoda and Lamellibranchiata of the Raritan Clays and Greensand Marls of New Jersey, by Rob rt P. Whitfield. 1885. 4°. xx, 338 pp. 35 pl. Price $1.15.

X. Dinocerata. A Monograph of an Extinct Order of Gigantic Mammals, by Othniel Charles Marsh. 1885. 4°. xviii, 243 pp. 56 l. 56 pl. Price $2.70.

XI. Geological History of Lake Lahontan, a Quaternary Lake of Northwestern Nevada, by Israel Cook Russell. 1885. 4°. xiv, 288 pp. 46 pl. Price $1.75.

BULLETINS.

1. On Hypersthene-Andesite and on Triclinic Pyroxene in Augitic Rocks, by Whitman Cross, with a Geological Sketch of Buffalo Peaks, Colorado, by S. F. Emmons. 1883. 8°. 42 pp. 2 pl. Price 10 cents.

2. Gold and Silver Conversion Tables, giving the coining values of troy ounces of fine metal, etc., by Albert Williams, jr. 1883. 8°. 8 pp. Price 5 cents.

3. On the Fossil Faunas of the Upper Devonian along the Meridian of 76° 30′ from Tompkins County, New York, to Bradford County, Pennsylvania, by Henry S. Williams. 1884. 8°. 36 pp. Price 5 cents.

4. On Mesozoic Fossils, by Charles A. White. 1884. 8°. 36 pp. 9 pl. Price 5 cents.

5. A Dictionary of Altitudes in the United States, compiled by Henry Gannett. 1884. 8°. 325 pp. Price 20 cents.

6. Elevations in the Dominion of Canada, by J. W. Spencer. 1884. 8°. 43 pp. Price 5 cents.

7. Mapoteca Geologica Americana. A Catalogue of Geological Maps of America (North and South), 1752–1881, by Jules Marcou and John Belknap Marcou. 1884. 8°. 184 pp. Price 10 cents.

8. On Secondary Enlargements of Mineral Fragments in Certain Rocks, by R. D. Irving and C. R. Van Hise. 1884. 8°. 56 pp. 6 pl. Price 10 cents.

9. Report of work done in the Washington Laboratory during the fiscal year 1883–'84. F. W. Clarke, chief chemist; T. M. Chatard, assistant. 1884. 8°. 40 pp. Price 5 cents.

10. On the Cambrian Faunas of North America. Preliminary Studies, by Charles D. Walcott. 1884. 8°. 74 pp. 10 pl. Price 5 cents.

11. On the Quaternary and Recent Mollusca of the Great Basin, with descriptions of new forms, by R. Ellsworth Call. Introduced by a Sketch of the Quaternary Lakes of the Great Basin, by G. K. Gilbert. 1884. 8°. 66 pp. 6 pl. Price 5 cents.

12. A Crystallographic Study of the Thinolite of Lake Lahontan, by Edward S. Dana. 1884. 8°. 34 pp. 3 pl. Price 5 cents.

13. Boundaries of the United States and of the several States and Territories, by Henry Gannett. 1885. 8°. 135 pp. Price 10 cents.

14. The Electrical and Magnetic Properties of the Iron-Carburets, by Carl Barus and Vincent Strouhal. 1885. 8°. 238 pp. Price 15 cents.

15. On the Mesozoic and Cenozoic Paleontology of California, by Charles A. White. 1885. 8°. 33 pp. Price 5 cents.

16. On the Higher Devonian Faunas of Ontario County, New York, by John M. Clarke. 1885. 8°. 86 pp. 3 pl. Price 5 cents.

17. On the Development of Crystallization in the Igneous Rocks of Washoe, Nevada, by Arnold Hague and Joseph P. Iddings. 1885. 8°. 44 pp. Price 5 cents.

18. On Marine Eocene, Fresh-water Miocene, and other Fossil Mollusca of Western North America, by Charles A. White. 1885. 8°. 26 pp. 3 pl. Price 5 cents.

19. Notes on the Stratigraphy of California, by George F. Becker. 1885. 8°. 28 pp. Price 5 cents.

20. Contributions to the Mineralogy of the Rocky Mountains, by Whitman Cross and W. F. Hillebrand. 1885. 8°. 114 pp. 1 pl. Price 10 cents.

21. The Lignites of the Great Sioux Reservation, by Bailey Willis. 1885. 8°. 16 pp. 5 pl. Price 5 cents.

22. On New Cretaceous Fossils from California, by Charles A. White. 1885. 8°. 25 pp. 5 pl. Price 5 cents.

23. Observations on the Junction between the Eastern Sandstone and the Keweenaw Series on Keweenaw Point, Lake Superior, by R. D. Irving and T. C. Chamberlin. 1885. 8°. 124 pp. 17 pl. Price 15 cents.

24. List of Marine Mollusca, comprising the Quaternary fossils and recent forms from American Localities between Cape Hatteras and Cape Roque, including the Bermudas, by William H. Dall. 1885. 8°. 336 pp. Price 25 cents.

25. The Present Technical Condition of the Steel Industry of the United States, by Phineas Barnes. 1885. 8°. 85 pp. Price 10 cents.

26. Copper Smelting, by Henry M. Howe. 1885. 8°. 107 pp. Price 10 cents.

27. Report of work done in the Division of Chemistry and Physics mainly during the fiscal year 1884–'85. 1886. 8°. 80 pp. Price 10 cents.

28. The Gabbros and Associated Hornblende Rocks occurring in the Neighborhood of Baltimore, Maryland, by George H. Williams. 1886. 8°. 78 pp. 4 pl. Price 10 cents.

29. On the Fresh-Water Invertebrates of the North American Jurassic, by Charles A. White. 1886. 8°. 41 pp. 4 pl. Price 5 cents.

30. Second Contribution to the Studies on the Cambrian Faunas of North America, by Charles D. Walcott. 1886. 8°. 369 pp. 33 pl. Price 25 cents.

31. A Systematic Review of our Present Knowledge of Fossil Insects, including Myriapods and Arachnids, by Samuel H. Scudder. 1886. 8°. 128 pp. Price 15 cents.

32. Lists and Analyses of the Mineral Springs of the United States, a Preliminary Study, by Albert C. Peale. 1886. 8°. 235 pp. Price 20 cents.

33. Notes on the Geology of Northern California, by Joseph S. Diller. 1886. 8°. 23 pp. Price 5 cents.

34. On the relation of the Laramie Molluscan Fauna to that of the succeeding Fresh-Water Eocene and other groups, by Charles A. White. 1886. 8°. 54 pp. 5 pl. Price 10 cents.

35. The Physical Properties of the Iron-Carburets, by Carl Barus and Vincent Strouhal. 1886. 8°. 62 pp. Price 10 cents.

36. Subsidence of Fine Solid Particles in Liquids, by Carl Barus. 1887. 8°. 58 pp. Price 10 cents.

37. Types of the Laramie Flora, by Lester F. Ward. 1887. 8°. 354 pp. 57 pl. Price 25 cents.

38. Peridotite of Elliott County, Kentucky, by Joseph S. Diller. 1887. 8°. 31 pp. 1 pl. Price 5 cents.

39. The Upper Beaches and Deltas of the Glacial Lake Agassiz, by Warren Upham. 1887. 8°. 84 pp. 1 pl. Price 10 cents.

STATISTICAL PAPERS.

Mineral Resources of the United States [1882], by Albert Williams, jr. 1883. 8°. xvii, 813 pp. Price 50 cents.

Mineral Resources of the United States, 1883 and 1884, by Albert Williams, jr. 1885. 8°. xiv, 1016 pp. Price 60 cents.

Mineral Resources of the United States, 1885. Division of Mining Statistics and Technology. 1886. 8°. vii, 576 pp. Price 40 cents.

Exchange.—The circular sent out in March, 1886, to all our correspondents for the purpose of verifying addresses has been very generally responded to, and from these responses the exchange list of over fifteen hundred addresses has been thoroughly revised and enlarged.

Eight thousand two hundred and twenty-three books and pamphlets have been received through the operations of the exchange during the year; Monographs IX, X, and XI, Bulletins Nos. 27 to 33, and the third Mineral Resources, for 1885, have been distributed to all entitled to complete exchange, as follows:

Bulletin 27	725	Bulletin 33	711
Bulletin 28	719	Monograph IX	723
Bulletin 29	717	Monograph X	711
Bulletin 30	765	Monograph XI	715
Bulletin 31	714	Mineral Resources, 1885	742
Bulletin 32	713		
			7,955

Sale.—Three thousand four hundred and three volumes have been sold this year as against 2,503 the previous year. This increase of 900 volumes in sales is due to no effort made by officers of the Survey to call attention to its publications, but to the increased interest therein on the part of the public.

The following table exhibits the sale account in detail:

Title of work.	Price of work.	Third quarter, 1886.		Fourth quarter, 1886.		First quarter, 1887.		Second quarter, 1887.		Whole fiscal year.	
Monograph II	$10.12	2	$20.24	2	$20.24	1	$10.12	2	$20.24	7	$70.84
Monograph III	11.00	1	11.00	1	11.00	1	11 00	2	22.00	5	55.00
Monograph IV	1.50	5	7.50	3	4.50	7	10.50	1	1.50	16	24.00
Monograph V	1.85	6	11.10	6	11.10	11	20.35	1	1.85	24	44.40
Monograph VI	1.05	3	3.15	3	3.15	3	3.15			9	9.45
Monograph VII	1.20	5	6.00	2	2.40	4	4.80	1	1.20	12	14.40
Monograph VIII	1.10	4	4.40	4	4.40	1	1.10	2	2.20	11	12.10
Monograph IX	1.15	2	2.30			2	2.30	3	3.45	7	8.05
Monograph X	2.70							1	2.70	1	2.70
Monograph XI	1.75					4	7.00	3	5.25	7	12.25
Bulletin 1	.10	4	.40	10	1.00	21	2.10	10	1.00	45	4.50
Bulletin 2	.05	3	.15	10	.50	21	.05	10	.50	44	2.20
Bulletin 3	.05	5	.25	8	.40	20	1.00	9	.45	42	2.10
Bulletin 4	.05	6	.30	10	.50	23	1.15	11	.55	50	2.50
Bulletin 5	.20	20	4.00	23	4.60	35	7.00	19	3.80	97	19.40
Bulletin 6	.05	5	.25	8	.40	19	.65	13	.65	45	2.25
Bulletin 7	.10	4	.40	8	.80	12	1.20	10	1.00	34	3.40
Bulletin 8	.10	[illegible]	.90	13	1.30	17	1.70	7	.70	46	4.60
Bulletin 9	.05	4	.20	11	.55	15	.75	14	.70	44	2.20
Bulletin 10	.05	4	.20	11	.55	19	.95	10	.50	44	2.20
Bulletin 11	.05	6	.30	9	.45	24	1.20	10	.50	49	2.45
Bulletin 12	.05	2	.10	8	.40	12	.60	6	.30	28	1.40
Bulletin 13	.10	13	1.30	10	1.00	25	2.50	12	1.20	60	6.00
Bulletin 14	.15	5	.75	14	2.10	14	2.10	8	1.20	41	6.15
Bulletin 15	.05	4	20	8	.40	14	.70	8	.40	34	1.70
Bulletin 16	.05	5	.25	7	.35	14	.70	9	.45	35	1.75
Bulletin 17	.05	7	.35	7	.35	14	.70	9	.45	37	1.85
Bulletin 18	.05	6	.30	9	.45	19	.95	12	.60	46	2.30
Bulletin 19	.05	1	.05	11	.55	12	.60	6	.30	30	1.50
Bulletin 20	.10	8	80	7	.70	27	2.70	13	1.30	55	5.50
Bulletin 21	.05	6	.30	8	.40	17	.85	14	.70	45	2.25
Bulletin 22	.05	7	.35	10	.50	14	.70	10	.50	41	2.05
Bulletin 23	.15	4	.60	10	1.50	15	2.25	6	.90	35	5.25
Bulletin 24	.25	7	1.75	12	3.00	15	3 75	8	2.00	42	10.50
Bulletin 25	.10	26	2.60	26	2.60	21	2.10	7	.70	80	8.00
Bulletin 26	.10	16	1.60	17	1.70	39	3.90	19	1.90	91	9.10
Bulletin 27	.10	1	.10	1	1.70	23	2.30	12	1.20	53	5.30
Bulletin 28	.10	150	15.00	13	1.30	21	2.10	12	1.20	196	19.60
Bulletin 29	.05	41	2.05	9	.45	17	.85	11	.55	78	3.90
Bulletin 30	.25					23	5.75	12	3.00	35	8.75
Bulletin 31	.15					220	33.00	9	1.35	229	34.35
Bulletin 32	.20			5	1.00	42	8.40	34	6.80	81	16.20
Bulletin 33	.05			170	8.50	51	2.55	8	.40	229	11.45
Bulletin 34	.10			20	2.00	11	1.10	9	.90	40	4.00
Bulletin 35	.10							158	15 80	158	15.80
Bulletin 36	.10							52	5.20	52	5.20
Bulletin 38	.05							1	.05	1	.05
Bulletin 39	.10							2	.20	2	.20
Mineral Resources, 1882	.50	34	17.00	31	15.50	67	33.50	41	20.50	173	86.50
Mineral Resources, 1883, 1884	.60	69	41.40	46	27.60	96	57.60	57	34.20	268	160.80
Mineral Resources, 1885	.40					308	123.20	161	64.40	469	187.60
Total		510	159.89	617	141.89	1,411	384.82	865	239.39	3,403	925.99

Whole number of volumes sold, 3,403.
Whole amount received for publications, $925.99.

Free distribution.—Besides the regular distribution by exchange and the sale as indicated above, 10,329 volumes were distributed gratuitously.

CORRESPONDENCE.

This division of the Survey handles all correspondence relating in any way to the exchange, distribution, or sale of publications of the Survey or the purchase of books or maps needed for the Survey. Eighteen thousand and twenty-three letters have been received, a daily average of over 60, and 15,562 letters have been sent out, a daily average of more than 51, during the last year.

I have again to refer with great satisfaction to the services of those upon whom I depend. Their duties are not always plain, but various and perplexing; they are brought into constant contact with the many personalities of the Survey and sometimes fail to satisfy the demands made upon them; but to their constant endeavor to do so and to their faithfulness is due the satisfactory condition of the work in this division.

Yours, very respectfully,

CHAS. C. DARWIN,
Librarian.

Hon. J. W. POWELL,
Director U. S. Geological Survey, Washington, D. C.

REPORT OF MR. JOHN D. McCHESNEY.

DEPARTMENT OF THE INTERIOR,
UNITED STATES GEOLOGICAL SURVEY,
Washington, D. C., September 30, 1887.

SIR: In compliance with your request, I have the honor to transmit herewith a statement of expenditures from the appropriation for the U. S. Geological Survey for the fiscal year ending June 30, 1887.

Respectfully yours,

JOHN D. McCHESNEY,
Chief Disbursing Clerk.

To the DIRECTOR,
U. S. Geological Survey.

Abstract of disbursements made by John D. McChesney, Chief Disbursing Clerk, U. S. Geological Survey, during the third quarter of 1886.

Date.	No. of voucher.	To whom paid.	For what paid.	Amount.
1886.				
July 20	1	D. J. Howell	Field supplies	$49.90
20	2	Washington City post-office	Rent of post-office boxes	8.00
20	3	Albert Williams, jr	Traveling expenses	36.60
20	4	W. J. McGee	......do	6.33
20	5	William M. Fontaine	......do	8.25
20	6	Frank Burns	......do	27.25
22	7	A. H. Brown	Services, July 1 to 19, 1886	80.00
24	8	Quartermaster's Department, U. S. Army.	Field material	140.62
24	9	.....do	..do	42.59
24	10	.....do	......do	19.60
24	11	E. H. King	Office furniture and repairs	85.40
27	12	William Hallock	Salary, July, 1886	184.80
28	13	Brentano Bros	Publications	9.25
31	14	Samuel H. Scudder	Salary, July, 1886	210.60
31	15	W. N. Merriam	......do	117.90
31	16	J. Henry Blake	......do	151.60
31	17	O. C. Marsh	......do	337.00
31	18	F. V. Hayden	......do	337.00
31	19	Philip C. Warman	......do	117.90
30	20	Cooper Curtis	Traveling expenses	26.80
30	21	Emil Starek	......do	5.58
31	22	F. W. Geiger	Salary, July, 1886	30.00
31	23	Pay-roll of employés	Services, July, 1886	264.80
31	24	Leo. Lesquereux	Salary, July, 1886	75.00
31	25	H. R. Geiger	......do	126.40
31	26	Thompson & McCaully	Care and forage of public animals	27.50
31	27	W. J. McGee	Salary, July, 1886	108.50
31	28	C. D. White	......do	81.00
31	29	Frank Burns	......do	75.80
31	30	Carroll Webster	Traveling expenses	4.50
31	31	Pay-roll of employés	Services, July, 1886	1,667.80
31	32	......do	......do	840.70
31	33	......do	......do	3,000.70
31	34	......do	......do	2,807.20
31	35	......do	......do	699.53
30	36	George W. Shutt	Salary, July, 1886	252.70
30	37	G. L. Johnson	......do	54.00
30	38	Mark M. Brighton	......do	50.50
Aug. 2	39	C. R. Van Hise	......do	108.00
2	40	N. S. Shaler	......do	270.00
2	41	James Longstreet, jr	......do	50.50
2	42	George H. Stone	......do	135.00
2	43	Robert Hay	......do	75.00
2	44	T. C. Chamberlin	......do	303.30
2	45	Nelson H. Darton	......do	100.00
2	46	Charles D. Walcott	......do	168.50
2	47	Pay-roll of employés	Services, July, 1886	262.20

Abstract of disbursements made by John D. McChesney, etc.—Continued.

Date.	No. of voucher.	To whom paid.	For what paid.	Amount.
1886.				
Aug. 2	48	Roland D. Irving	Salary, July, 1886	$252.70
3	49	J. Loring Whittington	Stationery	7.95
3	50	James G. Bowen	Care and forage of public animals	65.25
3	51	G. Baur	Services, July, 1886	140.00
3	52	L. P. Bush	do	50.00
3	53	H. Gibb	do	60.00
3	54	H. L. Reynolds	do	60.60
3	55	C. G. Van Hook	do	60.60
5	56	Pay-roll of employés	do	245.00
5	57	do	do	688.85
6	58	Johnson Bros	Fuel	67.00
5	59	Robert Hay	Traveling expenses	59.50
5	60	Pay-roll of employés	Services, July, 1886	690.80
5	61	do	do	204.30
7	62	D. J. Howell	Field expenses	44.25
9	63	George F. Becker	Salary, July, 1886	337.00
9	64	C. H. Pease	Field subsistence	20.45
9	65	W. S. Frazier & Co	Field material	377.16
9	66	George P. Money	Services, July, 1886	50.50
9	67	Washington Gas-light Company	Gas for July, 1886	61.05
12	68	J. S. Topham	Field material	54.00
12	69	H. R. Geiger	Traveling expenses	80.35
12	70	Bailey Willis	Field expenses, July, 1886	63.78
12	71	Joseph F. Page	Repairing camp-stove	3.18
12	72	C. C. Vermeule	Cash paid for instruments	50.75
12	73	P. H. Bevier	Traveling expenses	75.45
12	74	C. C. Vermeule	do	83.60
12	75	I. C. Russell	Cash paid for field expenses	129.60
12	76	Asher Atkinson	Traveling expenses	85.60
13	77	Robert T. Hill	do	18.10
13	78	Richard Thornton	Washing towels	.85
13	79	Thomas Hampson	Traveling expenses	3.20
14	80	William D. Castle	Field, office, and laboratory supplies	18.30
14	81	S. J. Haislett	Field supplies	186.90
16	82	Jefferson Middleton	Traveling expenses	28.60
16	83	J. E. Todd	Services, July 5 to 31, 1886	120.00
16	84	George H. Williams	Services, July 8 to August 10, 1886	145.00
17	85	Z. D. Gilman	Photographic and laboratory supplies.	262.66
17	86	W. Beck	Salary for July, 1886	110.00
17	87	Quartermaster's Department, U. S. Army.	Field material	78.56
18	88	Baltimore and Ohio Railroad Company.	Transportation of assistants	16.50
18	89	do	do	85.65
18	90	Pennsylvania Railroad Company	do	13.00
18	91	Hensel, Buckmann & Lorbacker	Freight on instruments, etc	15.30
18	92	Alf. E. Barlow	Tracing of map	25.00
18	93	E. F. Brooks	Office supplies	2.80
18	94	M. W. Beveridge	Field material	19.01
18	95	C. Schneider	Office supplies and repairs	11.45
19	96	William M. Fontaine	Salary, July, 1886	168.50
19	97	James Stevenson	Traveling expenses	16.75
25	98	John C. Parker	Publications	192.75
25	99	Nelson H. Darton	Traveling expenses	51.46
25	100	Henry J. Biddle	Field expenses	4.45
25	101	Nelson H. Darton	Cash paid for field expenses	5.79
25	102	Woodward & Lothrop	Cotton cloth	42.62
25	103	New York and New England Railroad Company.	Transportation of assistants	12.25
26	104	William J. Park & Co	Stationery, etc	16.90
26	105	James E. Moseley	Photographic supplies	7.38
26	106	L. C. Wooster	Services, July 16 to August 21, 1886	128.00
26	107	Chicago, Burlington and Quincy Railroad.	Transportation of assistants	13.55
26	108	F. V. Hayden	Traveling expenses	35.75
26	109	Baltimore and Ohio Railroad Co	Transportation of assistants	382.65
26	110	Gustav E. Stechert	Publications	118.45
26	111	do	do	64.24
31	112	Robert T. Hill	Salary for August, 1886	68.48
31	113	J. Henry Blake	do	151.60
31	114	William Hallock	do	134.80
31	115	James D. and E. S. Dana	Publications	1.50
31	116	P. D. Staats	Traveling expenses	90.54
31	117	W. H. Luster, jr	do	79.73
31	118	W. F. Marvine	do	33.38
31	119	A. A. Titsworth	do	81.40
31	120	Leo Lesquereux	Salary for August, 1886	75.00

Abstract of disbursements made by John D. McChesney, etc.—Continued.

Date.	No. of voucher.	To whom paid.	For what paid.	Amount.
1886.				
Aug. 31	121	H. F. Walling	Salary for August, 1886	$168.50
31	122	W. S. Bayley	Salary, July 7 to August 31, 1886	72.26
31	123	W. N. Merriam	Salary for August, 1886	117.90
31	124	Sam. H. Scudder	do	210.00
31	125	J. Belknap Marcon	do	101.10
31	126	H. R. Geiger	do	126.40
31	127	Nelson H. Darton	do	100.00
31	128	F. W. Geiger	do	30.00
31	129	A. C. Peale	do	168.50
31	130	C. R. Van Hise	do	118.00
31	131	Roland D. Irving	do	252.70
31	132	Charles D. Walcott	do	168.50
31	133	C. R. Van Hise	Traveling expenses	44.83
31	134	T. A. Polleys	Services	12.50
31	135	Freemont, Elkhorn and Missouri Valley Railroad Company.	Transportation of assistants	2.20
31	136	Roland D. Irving	Traveling expenses	134.18
31	137	Pay-roll of employés	Services for August, 1886	2,629.15
31	138	do	do	1,148.96
31	139	do	do	2,555.34
31	140	do	do	1,448.62
31	141	do	do	424.65
31	142	do	do	856.26
30	143	George W. Shutt	Salary for August, 1886	252.70
30	144	Frank Burns	do	75.80
30	145	Pay-roll of employés	Services for August, 1886	264.80
Sept. 1	146	G. Baur	Services, August, 1886	140.00
1	147	H. Gibb	do	60.00
1	148	L. P. Bush	do	50.00
1	149	Robert Beall	Publications	33.00
1	150	G. F. Becker	Salary, August, 1886	337.00
1	151	C. D. White	do	78.00
Aug. 31	152	Ernest P. Kübel	do	54.00
Sept. 1	153	Frank Burns	Traveling expenses	24.78
1	154	Albert Williams, jr	Salary, August, 1886	202.20
1	155	N. S. Shaler	do	200.00
Aug. 30	156	R. S. Woodward	Traveling expenses	64.75
31	157	Godfred A. Hornig	Salary, August, 1886	39.00
Sept. 1	158	Thompson & McCaully	Care and forage of public animals	26.50
1	159	Chas. Erhardt	Photographic material	5.00
2	160	W. H. Walmsley & Co	Photographic supplies	24.15
2	161	do	do	9.60
2	162	William York	Services, August 2 to 7, 1886	10.00
2	163	H. B. Swain	do	30.00
2	164	H. Rosendale	Instruments and repairs	19.30
2	165	G. L. Johnson	Salary, August 1 to 15, 1886	24.00
2	166	Lutz & Bros	Field material	65.50
2	167	James G. Bowen	Care and forage of public animals	70.25
2	168	Washington Gas-light Company	Gas for August, 1886	44.70
3	169	C. S. Cudlip	Photographic material	307.83
3	170	D. J. Howell	Field expenses	59.50
4	171	Joseph H. Wheat	Salary, August, 1886	45.66
4	172	N. B. K. Hoffman	Traveling expenses	38.07
4	173	Marcus Baker	Salary, August, 1886	202.20
4	174	C. W. Hawkins	do	46.77
4	175	Laurence Thompson	do	75.80
4	176	Van H. Manning, jr	do	55.76
4	177	F. V. Hayden	do	337.00
4	178	F. W. Bennett	Traveling expenses	77.07
4	179	N. Landon Burchell	Salary, August, 1886	60.00
4	180	Sumner H. Bodfish	do	168.50
4	181	S. A. Aplin	do	75.80
4	182	E. B. Clark	do	60.60
4	183	M. T. Burns	do	55.00
4	184	R. H. Phillips	do	75.80
4	185	Clifford Arrick	do	65.87
6	186	Geo. P. Money	do	55.76
6	187	A. Lamme & Co.	Field supplies	16.08
6	188	do	Field subsistence	48.35
6	189	Robert T. Hill	Traveling expenses	39.00
6	190	James S. Topham	Leather wallet	2.50
6	191	Brown & Sharpe Manufacturing Company	Instruments, etc	4.14
6	192	Charles J. Tagliabree	Laboratory supplies	38.25
6	193	J. K. Hillers	Traveling expenses	33.35
7	194	Robert Hay	Services, August, 1886	75.00
7	195	H. L. Hinkle & Bro	Fuel	48.44
7	196	J. E. Todd	Services, August 1 to 31, 1886	130.00
7	197	James Longstreet, jr	Services, August 1 to 15, 1886	24.46

Abstract of disbursements made by John D. McChesney, etc.—Continued.

Date.	No. of voucher.	To whom paid.	For what paid.	Amount.
1886.				
Sept. 7	198	Virginia Midland Railway Company.	Transportation of assistants	$58.00
7	199	T. C. Chamberlin	Salary, August, 1886	303.30
7	200	Fred. Brown	Pay, July 1 to August 31, 1886	180.00
7	201	O. C. Marsh	Salary, August, 1886	337.00
7	202	Frank Leverett	Salary, July and August, 1886	159.00
7	203	J. P. White	Salary, September 1 to 5, 1886	6.75
7	204	Warren Upham	Salary, July and August, 1886	202.20
7	205	Gayton A. Douglas	Photographic materials, etc	71.80
7	206	......do	......do	11.58
7	207	Cleverly Electric Works	Instruments	1.25
7	208	Richard R. Thornton	Washing towels	1.56
7	209	Union Stone Company	Laboratory supplies	33.88
7	210	J. P. White	Services, August 23 to 30, 1886	8.00
8	211	John E. Hill	Traveling expenses	116.49
8	212	Asher Atkinson	......do	77.69
8	213	C. C. Vermeule	......do	32.73
8	214	Pay-roll of employés	Services for August, 1886	740.87
8	215	......do	......do	192.00
8	216	David T. Day	Services, July and August, 1886	280.00
8	217	Pay-roll of Employés	Services for August, 1886	262.20
8	218	George F. Merrill	Traveling expenses	41.80
8	219	A. C. Peale	......do	44.30
8	220	George W. Shutt	......do	18.50
8	221	Elliott P. Hough	......do	24.65
9	222	A. A. Titsworth	......do	80.32
9	223	W. H. Luster, jr	......do	58.54
9	224	William F. Marvine	......do	26.83
9	225	P. D. Staats	......do	77.08
9	226	N. B. K. Hoffman	......do	25.51
9	227	Pay-roll of employés	Services, August, 1886	92.56
9	228	......do	......do	653.38
9	229	F. W. Bennett	Traveling expenses	55.35
9	230	Pay-roll of employés	Services, August, 1886	291.77
10	231	P. H. Bevier	Traveling expenses	107.73
10	232	Eastman Dry-plate and Film Company.	Photographic material	13.20
10	233	George H. Stone	Salary, August, 1886	130.00
10	234	Adams Express Company	Freight charges for July, 1886	231.25
10	235	R. D. Salisbury	Salary, July and August, 1886	240.00
10	236	Z. D. Gilman	Photographic and laboratory supplies.	142.94
10	237	W. J. McGee	Traveling expenses	85.25
10	238	Henry Garnett	......do	72.65
11	239	Robert T. Hill	......do	64.65
11	240	W. J. Grambs	Pay for August, 1886	68.48
29	241	George Cartner	Publications	7.00
30	242	Frank Burns	Pay for September, 1886	73.40
30	243	F. W. Clarke	Traveling expenses	85.04
30	244	Frank Burns	......do	29.30
30	245	F. W. Green & Co	Field supplies	12.66
30	246	Bailey Willis	......do	57.52
30	247	Leo Lesquereux	Salary, September, 1886	75.00
30	248	Pay-roll of employés	Services, September, 1886	260.40
30	249	C. G. Rockwood, jr	Traveling expenses	36.75
30	250	C. R. Van Hise	......do	75.00
30	251	Roland D. Irving	......do	164.44
30	252	Bailey Willis	Salary, September, 1886	195.60
30	253	Robert Hay	......do	75.00
30	254	L. C. Wooster	Traveling expenses	126.95
30	255	O. C. Marsh	Salary, September, 1886	326.00
30	256	W. J. Mayer	Services, July 1 to September 30, 1886	150.00
30	257	L. P. Bush	Services, September, 1886	50.00
30	258	W. Beck	Services, August, 1886	110.00
30	259	H. Gibb	Services, September, 1886	60.00
30	260	G. Baur	......do	140.00
30	261	R. W. Westbrook	Services, July 1 to September 30, 1886	150.00
30	262	A. Hermann	......do	225.00
30	263	M. P. Felch	Services, August, 1886	170.00
30	264	T. A. Bostwick	Services, July 1 to September 30, 1886	225.00
30	265	F. V. Hayden	Salary, September, 1886	326.00
30	266	H. R. Geiger	......do	122.20
30	267	F. W. Geiger	......do	30.00
30	268	William M. Fontaine	......do	163.00
30	269	Sam. H. Scudder	......do	203.80
30	270	Robert T. Hill	......do	73.40
30	271	Fessenden N. Chase	......do	50.00
30	272	Henry T. Hill	......do	14.66
30	273	W. E. Horton	Salary, August 11 to 31, 1886	33.86
30	274	The Hammond Typewriter Company.	One typewriter	100.00

Abstract of disbursements made by John D. McChesney, etc.—Continued.

Date.	No. of voucher.	To whom paid.	For what paid.	Amount.
1886.				
Sept. 30	275	T. C. Chamberlin	Salary, September, 1886	$293.40
30	276	H. F. Walling	......do	163.00
30	277	Nelson H. Darton	......do	100.00
30	278	W. P. Rust	Salary, July 1 to August 31 1886	124.55
30	279	Charles D. Walcott	Salary, September, 1886	163.00
30	280	A. C. Peale	......do	163.00
30	281	Marcus Baker	......do	195.60
30	282	J. Belknap Marcon	......do	97.80
30	283	Roland D. Irving	......do	244.60
30	284	George W. Cook	Salary, September 1 to 16, 1886	82.00
30	285	Geo. P. Money	Salary, September, 1886	58.80
30	286	J. Henry Blake	Services, September, 1886	146.80
30	287	N. S. Shaler	Salary, September, 1886	260.00
30	288	Ira Sayles	......do	195.60
28	289	George W. Shutt	......do	244.60
30	290	Pay-roll of employés	Services, September, 1886	683.40
30	291	......do	......do	2,241.80
30	292	......do	......do	904.60
30	293	......do	......do	3,008.50
30	294	......do	......do	1,311.20
30	295	C. W. Hawkins	......do	50.00
30	296	W. H. Dall	......do	163.00
30	297	D. J. Howell	Expenses, September, 1886	93.41
30	298	W. S. Bayley	Services, September, 1886	40.00
				57,131.96

SALARIES, OFFICE OF THE DIRECTOR.

1886.				
July 30	1	Pay-roll of employés	Services, July, 1886	2,833.20
30	2	Thomas J. Ryder	......do	84.20
Aug. 2	3	Jefferson Middleton	......do	75.80
14	4	E. N. McElhone	Services, August 1 to 15, 1886	29.35
31	5	Pay-roll of employés	......do	2,823.99
30	6	Thomas J. Ryder	......do	84.20
Sept. 7	7	Hersey Monroe	......do	24.46
30	8	Thomas J. Ryder	Services, September, 1886	81.60
30	9	Pay-roll of employés	......do	2,758.20
				8,795.00

Abstract of disbursements made by C. D. Davis, special disbursing agent, U. S. Geological Survey, during the third quarter of 1886.

1886.				
Sept. 17	1	Robert Hay	Traveling expenses	$43.87
18	2	H. R. Geiger	......do	86.20
20	3	J. B. Bean	Hire of horses, wagon, etc	253.75
20	4	Noah R. King	Services, August 16 to September 20, 1886.	57.47
20	5	James Forrestell	......do	68.97
20	6	Daniel Morganstern	Hire of horse	26.25
20	7	C. W. Curtis	Services, September 1 to 15, 1886	32.50
20	8	A. Randall	......do	12.50
21	9	W. F. Madden & Co	One adding machine	13.50
24	10	William Kramer	Services, August, 1886	50.00
24	11	Eugene E. Pierce	......do	50.00
24	12	Ira M. Buell	Services, July 8 to September 10, 1886.	208.00
25	13	George M. Geddes	Services, September 1 to September 25, 1886.	44.00
25	14	L. S. Hayden	Publications	15.00
30	15	James A. Maher	Services, September, 1886	97.80
30	16	John L. Ridgway	......do	97.80
				1,157.61

Abstract of disbursements made by H. C. Rizer, disbursing agent, U. S. Geological Survey, during the third quarter of 1886.

Date.	No. of voucher.	To whom paid.	For what paid.	Amount.
1886.				
July 24	1	H. D. Lyman	1 mule	$60.00
31	2	Pay-roll	Services, July, 1886	745.14
31	3	do	do	565.55
31	4	do	do	576.30
27	5	Charles H. Fitch	Traveling expenses	67.10
29	6	Hamilton S. Wallace	do	29.25
29	7	A. H. Thompson	do	82.45
29	8	E. M. Douglas	do	17.75
31	9	A. H. Thompson	Services, July 1 to 31, 1886	227.40
31	10	H. C. Rizer	do	151.60
31	11	Paul Holman	do	70.80
Aug. 3	12	Charles A. Garlick	do	60.00
3	13	Charles F. Urquhart	Traveling expenses	58.80
4	14	E. M. Douglas	Field expenses	60.20
4	15	A. F. Dunnington	do	30.75
4	16	R. U. Goode	do	77.91
4	17	do	Traveling expenses	10.15
10	18	Edward A. Oyster	Services, July 16 to 31, 1886	81.25
July 31	19	Pay-roll	Services, July, 1886	730.90
Aug. 11	20	Paul Weber	Services, July 1 to 31, 1886	55.00
July 31	21	Pay-roll	Services, July, 1886	340.00
31	22	do	do	306.60
Aug. 13	23	E. C. Ryan	Services, July 1 to 31, 1886	50.00
13	24	John ——	do	40.00
3	25	A. F. Dunnington	Traveling expenses	110.00
16	26	Paul Holman	do	16.50
16	27	M. Edwards & Co	Field subsistence	224.04
16	28	Henry Exall	2 mules	150.00
16	29	Payne & Choate	Field material	101.85
16	30	do	Labor and material	79.85
16	31	Hurlfret & Semple	Field material	26.40
16	32	A. Lamme & Co	do	49.11
16	33	do	Field subsistence	113.18
16	34	Highsmith & Bean	Labor and material	72.85
16	35	George E. Howard	Forage and corral	52.25
16	36	William Ennis	Field subsistence	75.05
16	37	David Rope	Pasturage	40.00
16	38	Adamson & Burbage	Field material	7.40
16	39	J. T. Luse	Field subsistence	10.08
16	40	L. B. Putney	do	5.09
16	41	B. H. Gilman	do	109.32
16	42	John H. Hughes	Field material	24.50
16	43	James T. Johnston	do	186.75
16	44	Adam Hanna	Labor	3.00
16	45	E. J. Post & Co	Field material	90.18
16	46	do	do	79.83
17	47	A. Grunsfield	do	111.15
17	48	Charles Hanwald	Field subsistence	9.10
17	49	William Ambruster	Labor and material	71.70
18	50	A. H. Thompson	Traveling expenses	131.20
18	51	A. M. Boyer	Board	12.50
18	52	Wells, Fargo & Co	Freight	3.00
14	53	J. J. Floreth	Job	.65
19	54	R. U. Goode	Field expenses	42.65
19	55	do	Traveling expenses	13.20
19	56	do	do	11.60
20	57	Mark B. Kerr	Field expenses	466.69
20	58	Eugene Ricksecker	do	487.54
20	59	Redick H. McKee	do	58.65
20	60	do	do	62.10
20	61	William B. Ross	Labor and material	70.00
20	62	D. M. Frieslebur	Board	35.25
20	63	F. J. Bringham	Field material	66.30
20	64	Perkins & Wise	Field subsistence	39.26
20	65	do	do	39.41
20	66	James C. Gray	Field material	39.08
20	67	H. M. Wilson	Field expenses	91.21
21	68	E. M. Douglas	do	105.90
23	69	W. G. Steel	Traveling expenses	18.43
23	70	W. R. Mayfield	Services, July 7 to 31, 1886	40.30
23	71	Sikes Wooden	1 mule	70.00
23	72	C. E. Dutton	Field expenses	404.80
23	73	H. M. Wilson	do	109.63
21	74	A. Lamme & Co	Field subsistence	42.00
21	75	E. J. Owenhouse	Field material	143.10
21	76	T. J. Kellam	Office	1.55
21	77	A. F. Dunnington	Field expenses	70.72
25	78	Redick H. McKee	do	92.65

Abstract of disbursements made by H. C. Rizer, etc.—Continued.

Date.	No. of voucher.	To whom paid.	For what paid.	Amount.
1886.				
Aug. 25	79	H. M. Wilson	Field expenses	$42.17
26	80	Frank H. Thorp	Traveling expenses	42.00
26	81	F. H. Thorp	Field expenses	13.90
26	82	R. U. Goode	......do	53.55
26	83	Edward A. Oyster	Traveling expenses	35.75
26	84	......do	......do	11.70
27	85	Brown & Kinder	Forage	30.29
27	86	A. P. Davis	Field expenses	45.77
27	87	Chas. A. Garlick	......do	24.60
27	88	Perkins & Wise	Field subsistence	105.09
28	89	M. Edwards & Co	......do	81.25
28	90	Payn & Choate	Repairs	4.50
28	91	A. F. Dunnington	Field expenses	45.67
28	92	B. H. Gilman	Field subsistence	38.68
30	93	R. H. Chapman	Services, August 1 to 15, 1886	31.24
30	94	Pay-roll	Services, July, 1886	408.00
30	95	......do	Services, August, 1886	250.87
30	96	......do	......do	346.60
30	97	......do	......do	401.60
30	98	......do	......do	298.50
31	99	......do	......do	237.17
30	100	Hamilton S. Wallace	Services, August 1 to 15, 1886	40.76
31	101	Atlantic and Pacific Railroad Company.	Freight	3.98
31	102	Pay-roll	Services, August 1 to 15, 1886	114.13
31	103	......do	Services, August, 1886	220.87
31	104	......do	......do	311.74
31	105	Redick H. McKee	Services, August 1 to 15, 1886	29.35
31	106	Paul Holman	Services, August 1 to 31, 1886	70.80
31	107	Pay-roll	Services, August, 1886	500.60
31	108	......do	......do	551.74
31	109	H. C. Rizer	Services, August 1 to 31, 1886	151.60
31	110	Percy L. Green	......do	70.80
31	111	Pay-roll	Services, August, 1886	369.78
Sept. 3	112	Atlantic and Pacific Railroad Company.	Freight	40.69
4	113	Chas. H. Fitch	Field expenses	49.25
Aug. 31	114	Pay-roll	Services, August, 1886	306.60
Sept. 4	115	B. H. Colegrove	Traveling expenses	32.75
4	116	A. F. Dunnington	Field expenses	40.00
4	117	Percy L. Green	Traveling expenses	41.50
Aug. 22	118	Western Union Telegraph Company.	Three messages	.73
Sept. 4	119	Chas. A. Garlick	Field expenses	40.64
4	120	Adamson & Burbage	Field material	35.00
4	121	W. W. McCullough	Subsistence	33.37
7	122	Western Union Telegraph Company.	Nineteen messages	6.21
7	123	Wells, Fargo & Company's Express.	Freight	6.75
8	124	W. G. Kenney	Horse	35.00
8	125	J. C. Kay	Subsistence	16.52
8	126	A. P. Davis	Field expenses	17.50
14	127	R. U. Goode	......do	120.70
14	128	Chas. F. Urquhart	Traveling expenses	18.35
14	129	Hamilton S. Wallace	Field expenses	20.00
14	130	C. H. Stone	Traveling expenses	37.65
14	131	W. H. Leffingwell	......do	44.27
14	132	E. M. Douglas	Field expenses	54.25
14	133	A. Lamme & Co	Subsistence	47.55
14	134	......do	Field material	27.10
14	135	Levy & Elias	......do	26.25
14	136	John Nissen	......do	29.79
14	137	Frank Tweedy	Field expenses	28.65
14	138	Chas. H. Fitch	......do	65.92
14	139	John H. Slocum	Forage	25.51
14	140	C. E. Dutton	Field expenses	400.17
Aug. 31	141	Pay-roll	Services, August, 1886	300.00
16	142	F. A. Cummings	Services, August 1 to 15, 1886	24.19
Sept. 16	143	Mark B. Kerr	Field expenses	252.88
17	144	Eugene Ricksecker	......do	124.95
18	145	A. H. Thompson	Services, August 1 to 31, 1886	227.40
18	146	Perkins & Wise	Field subsistence	61.25
20	147	......do	......do	46.05
20	148	H. M. Wilson	Field expenses	174.75
20	149	Paul Holman	......do	38.50
20	150	Western Union Telegraph Company.	Eleven messages	4.91
27	151	H. C. Rizer	Traveling expenses	84.10

Abstract of disbursements made by H. C. Rizer, etc.—Continued.

Date.	No. of voucher.	To whom paid.	For what paid.	Amount.
1886.				
Sept. 27	152	D. B. Sanborn	Two mules	$250.00
27	153	William Ennis	Subsistence	50.15
28	154	R. D. Cunningham	Field material	192.50
28	155	G. G. Bissell	Field expenses	27.85
28	156	H. S. Wallace	......do	38.41
30	157	Fred T. Dean	Services, July 22 to September 30, 1886.	58.06
30	158	Pay-roll	Services, September, 1886	297.80
30	159	......do	......do	833.00
30	160	......do	......do	865.20
30	161	......do	......do	474.96
30	162	......do	......do	274.20
30	163	......do	......do	253.33
30	164	......do	......do	520.40
30	165	......do	......do	128.69
30	166	......do	......do	345.40
30	167	A. H. Thompson	......do	220.20
30	168	H. C. Rizer	......do	146.80
30	169	R. U. Goode	Field expenses	85.35
30	170	A. F. Dunnington	......do	47.54
30	171	......do	......do	15.25
30	172	F. H. Thorp	Services, July 15 to 31, 1886	27.40
30	173	A. F. Dunnington	Field expenses	33.85
30	174	Redick H. McKee	......do	146.88
30	175	Charles H. Fitch	......do	67.50
30	176	Frank Senn	Services, September 9 to 30, 1886	29.33
30	177	Alpha Hassler	Services, July 15 to August 30, 1886	77.40
30	178	......do	Traveling expenses	11.25
30	179	Pay-roll	Services, September, 1886	401.80
				21,923.46

Abstract of disbursements made by P. H. Christie, special disbursing agent, U. S. Geological Survey, during the third quarter of 1886.

Date.	No. of voucher.	To whom paid.	For what paid.	Amount.
1886.				
July 15	1	Bergman Manufacturing Company.	Field material	$56.00
15	2	L. C. Fletcher	Traveling expenses	13.80
15	3	L. P. & H. C. Ott	Field material and supplies	24.76
15	4	Rohr Brothers	......do	58.76
15	5	William J. O'Connell	Traveling expenses	2.75
15	6	Snell Brothers & Co	Subsistence	25.17
15	7	N. L. Greiner	Field material	7.40
15	8	B. B. Bowman	Stock	125.00
15	9	M. L. Grove	......do	134.00
15	10	R. O. Gordon	Traveling expenses	6.05
15	11	M. O. Crabill	Hire of transportation, etc	14.25
15	12	Mrs. M. C. Lupton	Subsistence	66.75
15	13	L. J. Golden	Smithing	9.70
15	14	J. P. Houck	Field material and supplies	63.97
15	15	C. A. Sprinkel & Son	Field material	96.60
17	16	Z. N. Lockhart	Stock	650.00
19	17	J. P. Houck	......do	267.50
19	18	Lutz & Bro	Field material	10.00
19	19	M. Hackett	Traveling expenses	7.25
19	20	W. T. Griswold	Miscellaneous field expenses	92.86
20	21	......do	......do	14.50
20	22	Edward A. Oyster	Services, July 1 to 15, 1886	29.35
20	23	......do	Traveling expenses	4.35
22	24	Read House	Subsistence	22.50
31	25	Pay-roll	Services, July, 1886	1,591.24
31	26	......do	......do	309.68
31	27	D. C. Harrison	Services, July 1 to 31, 1886	75.80
31	28	R. L. Longstreet	......do	75.80
31	29	R. C. McKinney	......do	75.80
31	30	J. W. Hays	......do	101.10
31	31	Charles M. Yeates	......do	151.60
31	32	John W. Carter	......do	25.00
31	33	M. F. Christie	......do	50.00
31	34	S. S. Gannett	......do	184.80
31	35	C. E. Sullivan	......do	40.00
31	36	L. J. Alden	Traveling expenses	2.00
31	37	Pay-roll	Services, July, 1886	396.10
31	38	R. C. Dunn	Services, July 1 to 31, 1886	40.00

Abstract of disbursements made by P. H. Christie, etc.—Continued.

Date.	No. of voucher.	To whom paid.	For what paid.	Amount.
1886.				
July 31	39	Conner J. Akin	Services, July 1 to 31, 1886	$50.00
Aug. 16	40	E. P. Lane	Traveling expenses	16.75
16	41	L. C. Fletcher	......do	4.25
16	42	R. McC. Mickler	......do	43.70
16	43	L. C. Fletcher	Miscellaneous field expenses	82.25
16	44	Edmunds Kennedy	Traveling expenses	5.40
16	45	S. S. Gannett	Miscellaneous field expenses	185.50
16	46	L. C. Fletcher	......do	52.94
16	47	Henry S. Selden	Traveling expenses	6.85
16	48	M. Hackett	Miscellaneous field expenses	11.01
16	49	L. C. Fletcher	......do	44.85
16	50	W. T. Griswold	Traveling expenses	9.75
16	51	Gaston Brown	......do	7.80
16	52	H. B. Blair	......do	22.75
16	53	J. P. Houck	Field material	86.95
16	54	N. B. Dunn	Stock	142.50
16	55	......do	......do	140.00
16	56	......do	Meals and lodgings, etc	87.85
16	57	......do	Forage of stock	166.55
16	58	......do	Smithing	43.65
16	59	W. T. Griswold	Miscellaneous field expenses	61.18
16	60	Frank M. Pearson	Traveling expenses	23.05
16	61	R. M. Towson	......do	25.85
16	62	Charles M. Yeates	......do	24.80
16	63	W. L. Miller	......do	19.90
16	64	R. Lee Longstreet	......do	3.05
16	65	Otto H. Schumacher	Field supplies	78.55
16	66	Fred P. Gulliver	Traveling expenses	7.75
16	67	Louis Nell	......do	34.30
17	68	......do	Miscellaneous field expenses	73.30
17	69	W. R. Atkinson	Traveling expenses	9.25
17	70	James Longstreet, jr	......do	9.60
17	71	Shack Smith	......do	1.75
17	72	C. H. and N. L. Halsey	Field supplies	23.92
18	73	J. W. Skinner	Repairs of field material	41.50
18	74	Michael Bergman	Field material	12.00
18	75	L. C. Fletcher	Miscellaneous field expenses	77.37
18	76	......do	......do	44.50
18	77	M. C. Barton	Subsistence	18.50
18	78	Fred J. Knight	Miscellaneous field expenses	80.23
18	79	S. S. Gannett	......do	69.50
18	80	W. T. Griswold	......do	92.25
18	81	Fred J. Knight	Traveling expenses	11.10
18	82	D. C. Harrison	......do	24.15
18	83	M. J. Holt	......do	17.55
18	84	C. W. Goodloe	......do	10.60
18	85	Frank M. Pearson	Miscellaneous field expenses	100.00
21	86	Morris Bien	......do	100.00
21	87	C. A. Robinson	Forage of stock	72.60
21	88	Fred. J. Knight	Miscellaneous field expenses	63.15
21	89	Turpin, Chestnut & Co	Subsistence	17.18
21	90	J. W. Hays	Traveling expenses	24.80
21	91	C. J. Akin	......do	9.40
21	92	W. T. Griswold	Miscellaneous field expenses	49.72
21	93	S. J. Haislett	Field material	136.80
31	94	Pay-roll	Services, August, 1886	243.46
31	95	M. Hackett	Services, August 1 to 31, 1886	77.72
31	96	H. D. A. Biemann	Subsistence, forage, etc	68.00
31	97	Pay-roll	Services, August, 1886	447.19
31	98	......do	......do	488.08
31	99	......do	......do	511.45
31	100	......do	......do	446.55
31	101	......do	......do	467.82
31	102	Mary Wilder	Services, August 15 to 31, 1886	13.71
31	103	John W. Carter	Services, August 1 to 31, 1886	25.00
31	104	V. T. Carmichael	Services, August 6 to 31, 1886	20.96
31	105	Pay-roll	Services, August, 1886	433.88
31	106	......do	......do	605.61
31	107	S. Herbert Giesy	Services, August 1 to 31, 1886	50.50
31	108	P. H. Christie	......do	151.60
31	109	M. T. Christie	......do	50.00
31	110	L. S. Woodward	Services, August 18 to 31, 1886	11.29
30	111	Elias Foglesong	Forage of stock, etc	56.03
31	112	James Lewis Howe	Services, August 21 to 31, 1886	8.87
31	113	W. F. Fling	Forage of stock	16.00
Sept. 6	114	Fred. A. Schmidt	Instruments	4.25
6	115	Anson S. Ward	Field supplies	6.60
6	116	R. H. Stewart	Traveling expenses	5.55
6	117	Louis Knell	Miscellaneous field expenses	158.18
6	118	Morris Bien	......do	101.85

Abstract of disbursements made by P. H. Christie, etc.—Continued.

Date.	No. of voucher.	To whom paid.	For what paid.	Amount.
1886.				
Sept. 6	119	M. Hackett	Miscellaneous field expenses	$49.36
6	120	Charles M. Yeates	do	124.06
6	121	L. C. Fletcher	do	58.54
6	122	do	do	47.35
6	123	W. T. Griswold	do	48.85
6	124	R. C. McKinney	Traveling expenses	17.80
11	125	John H. Buxton	Field material	6.00
11	126	L. C. Fletcher	Miscellaneous field expenses	55.50
11	127	Fred. J. Knight	do	68.34
11	128	Morris Bien	do	71.75
13	129	Louis Nell	do	91.15
13	130	H. Herzberg	Stock	150.00
13	131	George E. Kennedy & Son	Subsistence	91.96
14	132	G. G. Cornwell & Son	do	33.01
18	133	R. E. Dietz	Field material	11.25
22	134	W. T. Griswold	Miscellaneous field expenses	22.58
22	135	do	do	56.97
22	136	do	do	35.55
22	137	do	do	28.22
22	138	do	do	10.70
22	139	Frank M. Pearson	do	209.97
22	140	L. C. Fletcher	do	59.25
22	141	Morris Bien	do	120.58
22	142	L. C. Fletcher	do	57.51
22	143	S. S. Gannett	do	224.28
22	144	Louis Nell	do	56.74
22	145	do	do	77.00
30	146	Pay-roll	Services, September, 1886	478.80
30	147	do	do	470.60
30	148	do	do	527.20
30	149	do	do	528.00
30	150	do	do	513.20
30	151	do	do	560.40
30	152	do	do	665.20
30	153	do	do	246.80
30	154	M. Hackett	Services, September 1 to 30, 1886	81.60
30	155	John W. Carter	do	25.00
30	156	P. H. Christie	do	146.80
30	157	Mary Wilder	do	25.00
30	158	V. T. Carmichael	do	25.00
30	159	M. T. Christie	do	50.00
30	160	James Lewis Howe	do	25.00
30	161	L. S. Woodward	do	25.00
30	162	W. F. Fling	Forage of stock	8.00
30	163	Fred. J. Knight	Miscellaneous field expenses	79.58
30	164	P. H. Christie	Traveling expenses	221.51
30	165	N. B. Dunn	Stock	135.00
30	166	W. T. Griswold	Miscellaneous field expenses	52.18
30	167	do	do	92.58
30	168	do	do	60.73
30	169	Frank M. Pearson	do	214.45
30	170	L. C. Fletcher	do	47.60
30	171	do	do	45.75
30	172	Fred. J. Knight	do	56.72
30	173	do	do	35.65
30	174	do	do	41.90
30	175	Charles M. Yeates	do	336.99
30	176	M. Hackett	do	57.10
30	177	Morris Bien	do	184.35
30	178	Fred J. Knight	do	35.05
30	179	Louis Nell	do	107.49
				19,886.16

Abstract of disbursements made by John H. Renshawe, disbursing agent, U. S. Geological Survey, during the third quarter of 1886.

1886.				
July 28	1	John H. Renshawe	Services, July 1 to 31, 1886	210.60
28	2	E. T. Perkins, jr	Traveling expenses	38.70
28	3	George T. Hawkins	do	39.20
29	4	William H. Herron	do	38.70
29	5	J. T. Richey	Tent flies, etc	35.00
29	6	W. T. Walker	Services, July 1 to 31, 1886	40.00
29	7	George Unsell	do	31.61
29	8	B. Murray	Hotel bill	33.25
29	9	C. E. Woodin	Services, July 1 to 31, 1886	30.00

Abstract of disbursements made by John H. Renshawe, etc.—Continued.

Date.	No. of voucher.	To whom paid.	For what paid.	Amount.
1886.				
July 29	10	M. Newmark	Field material	38.60
29	11	Abe Levy	Camp chest	5.00
29	12	J. H. Dailey	Table-ware	28.25
29	13	A. M. Ulrickson	Field material	80.70
30	14	George Unsell	Traveling expenses	8.60
30	15	Lincoln Cook	Services, July 1 to 31, 1886	11.60
30	16	J. H. Glathart	1 horse	125.00
31	17	William J. Peters	Traveling expenses	32.75
31	18	E. C. Quackenbush	do	19.50
31	19	S. H. Brown	Lumber, etc	16.85
31	20	E. C. Quackenbush	Services, July 6 to 31, 1886	29.35
Aug. 2	21	H. W. Henderson	Saddlery, etc	83.80
2	22	W. G. Melville	Carpenter work	39.32
2	23	Henry Frey	Blacksmithing, etc	120.00
2	24	Johnson & Engstrom	do	10.80
3	25	S. Steinberg	Field material	14.00
4	26	Herbert B. Taylor	Traveling expenses	13.75
4	27	William J. Peters	Field expenses	20.15
5	28	W. H. Pendleton	Subsistence	167.14
5	29	L. C. Graves	Pasturage	15.00
5	30	Pearce & Hollingbery	Forage	33.25
5	31	P. Bradley	Fresh beef	2.00
5	32	Eidemiller & Co	Forage	3.20
5	33	Johnson & Cunnington	Fresh beef	10.50
6	34	Kimbal Brothers	Tent pins	2.50
6	35	H. L. Baldwin, jr	Traveling expenses	47.35
6	36	M. E. Atchinson	do	6.65
12	37	T. F. Kirby	Lumber, etc	21.85
16	38	F. M. Stark	do	14.86
18	39	Basil Duke	Traveling expenses	12.50
18	40	F. P. Metzger	do	13.50
18	41	William H. Herron	do	40.90
18	42	C. T. Reed	do	12.50
18	43	William J. Peters	Services, July 1 to 31, 1886	84.20
18	44	S. E. Atchinson	do	35.00
19	45	Eli C. Baker	Mules and harness	358.00
19	46	do	Hire of team	30.00
21	47	G. W. Toothaker	Board of horse	6.25
24	48	do	1 horse	160.00
27	49	H. L. Baldwin, jr	Services, July 1 to 31, 1886	75.80
27	50	do	Field expenses	140.54
28	51	John H. Renshawe	do	167.59
21	52	Western Union Telegraph Company.	Official telegram	2.01
28	53	William J. Peters	Field expenses	47.15
30	54	W. H. Pendleton	Subsistence, etc	52.88
31	55	John H. Renshawe	Services, August 1 to 31, 1886	210.60
Sept. 27	56	H. L. Baldwin, jr	Services, August 1 to 15, 1886	36.68
27	57	do	Services, August 16 to September 30, 1886.	149.97
27	58	William J. Peters	Services, August 1 to September 30, 1886.	165.80
27	59	George T. Hawkins	Services, July 15 to August 15, 1886	105.04
30	60	do	Services, August 16 to September 30, 1886.	112.58
27	61	E. T. Perkins, jr	Services, July 1 to August 15, 1886	89.95
27	62	do	Services, August 16 to September 30, 1886.	112.58
27	63	William H. Herron	Services, July 1 to August 31, 1886	101.00
27	64	W. H. Reynolds	Services, July 16 to August 31, 1886	75.81
27	65	Herbert B. Taylor	do	75.81
27	66	Basil Duke	Services, August 9 to 31, 1886	37.10
27	67	F. P. Metzger	do	37.10
27	68	C. T. Reed	do	37.10
27	69	Henry A. Koster	Services, August 14 to September 20, 1886.	61.66
27	70	W. W. Nutz	Services, August 23 to September 30, 1886.	32.25
30	71	W. C. Fritter	Services, August 1 to 31, 1886	25.00
27	72	W. T. Walker	do	40.00
27	73	S. E. Atchinson	do	35.00
27	74	C. E. Woodin	Services, August 1 to September 30, 1886.	60.00
27	75	E. C. Quackenbush	Services, August 1 to September 7, 1886.	43.16
27	76	George Unsell	Services, August 1 to September 30, 1886.	70.00
27	77	M. E. Atchinson	Services, July 20 to August 31, 1886	41.60
27	78	Lincoln Cook	Services, August 1 to September 30, 1886.	60.00

Abstract of disbursements made by John H. Renshawe, etc.—Continued.

Date.	No. of voucher.	To whom paid.	For what paid.	Amount.
1886.				
Sept. 27	79	Henry H. Koster	Traveling expenses	$10.95
27	80	W. H. Pendleton	Subsistence	45.50
27	81	H. L. Baldwin	Field expenses	59.78
27	82	H. W. Henderson	Saddlery, etc	20.05
27	83	William J. Peters	Field expenses	56.84
27	84	......do	......do	17.75
27	85	......do	......do	18.05
27	86	John C. Robertson	Traveling expenses	7.50
30	87	H. L. Baldwin, jr	Field expenses	89.15
30	88	John C. Robertson	Traveling expenses	21.00
30	89	......do	Services, August 9 to 31, 1886	87.10
30	90	W. H. Gardener	Subsistence, etc	83.42
30	91	John H. Renshawe	Field expenses	172.07
		Total		5,178.05

Abstract of disbursements made by Arnold Hague, special disbursing agent, U. S. Geological Survey, during the third quarter of 1886.

1886.				
Aug. 6	1	W. H. Weed	Traveling expenses	$68.18
6	2	William Hallock	......do	123.40
10	3	W. E. Scott & Co	Nettleton current-meter	130.00
10	4	George C. Howard	Care and forage of public animals	89.75
10	5	A. Lamme & Co	Field materials, subsistence, etc	77.12
10	6	E. J. Owenhouse	Field supplies and repairs	48.95
10	7	A. T. Elliot	Drayage on public property	7.50
Sept. 2	8	Samuel L. Penfield	Traveling expenses	104.60
3	9	George W. Colpitts	Repairing ambulance	22.75
20	10	Henry J. Green	Instruments and repairs	67.75
24	11	Northern Pacific Express Company, George W. Wakefield, agent.	Expressage	56.15
24	12	T. R. Mallon	Field subsistence	80.01
27	13	Northern Pacific Express Company.	Expressage	2.27
				878.43

Abstract of disbursements made by G. K. Gilbert, special disbursing agent, U. S. Geological Survey, during the third quarter of 1886.

1886.				
July 6	1	George W. Whitehead	Punch	$3.50
30	2	P. C. Warman	Traveling expenses	19.75
16	3	E. P. Webb	Atlas	2.00
30	4	American Express Company	Expressage	.75
30	5	G. K. Gilbert	Traveling expenses	141.84
31	6	......do	Services, July 1 to 31, 1886	337.00
Aug. 4	7	American Express Company	Expressage	1.50
19	8	G. K. Gilbert	Traveling expenses	109.77
31	9	P. C. Warman	......do	13.95
26	10	American Express Company	Expressage	.50
31	11	G. K. Gilbert	Services, August 1 to 31, 1886	337.00
Sept. 24	12	......do	Traveling expenses	112.75
30	13	......do	Services, August 1 to 31, 1886	326.00
				1,406.31

Abstract of disbursements made by R. R. Hawkins, special disbursing agent, U. S. Geological Survey, during the third quarter of 1886.

1886.				
July 31	1	Pay-roll	Services, July, 1886	$574.40
Aug. 19	2	Carl Rabe	Services, July 1 to 31, 1886	45.00
19	3	George Phillips	......do	50.00
19	4	Albion S. Howe	......do	60.00
19	5	F. C. Boyce	......do	60.00

Abstract of disbursements made by R. R. Hawkins, etc.—Continued.

Date.	No. of voucher.	To whom paid.	For what paid.	Amount.
1886.				
Aug. 23	6	G. W. Maxon	Mules	$270.00
23	7	S. L. Daniels	Mules and horses	420.00
31	8	Pay-roll	Services, August, 1886	583.13
31	9	Albion S. Howe	Services, August 1 to 31, 1886	60.00
26	9a	H. W. Turner	Traveling expenses	32.95
31	10	Carl Rabe	Services, August 1 to 31, 1886	45.00
31	11	George Phillips	......do	50 00
Sept. 11	12	H. Davis	Cartage and labor	10.25
Aug. 13	13	W. Lindgren	Field expenditures	67.34
Sept. 13	14	A. H. Weber	Services, July 15 to 31, 1886	20.00
Sept. 13	15	......do	Services, August 1 to 31, 1886	40.00
13	15a	W. Lindgren	Field expenditures	20.00
14	16	T. J. Housh	Horse	75.00
20	17	Neville & Co	Tent	18.00
20	18	F. C. Boyce	Services, August 1 to 31, 1886	68.00
20	19	A. H. Weber	Services, September 1 to 15, 1886	20.00
20	20	Maine & Winchester	Harness, saddles, etc	127.17
20	21	......do	......do	101.75
22	22	H. W. Turner	Field expenditures	76.73
22	23	......do	Traveling expenses	35.49
24	24	W. Lindgren	Field expenditures	39.91
25	25	Carl Rabe	Services, September 1 to 24, 1886	36.00
25	26	......do	Traveling expenses	12.75
27	27	Goldberg, Bowen & Co	Field supplies	110.53
27	28	......do	......do	30.81
27	29	Perkins, Wise & Ostroski	......do	34.51
27	30	H. L. Howse	Laboratory supplies	28.20
28	31	J. J. Vasconcellos	Supplies	47.80
28	32	A. Lietz & Co	Supplies, etc	21.50
28	33	Wempee Brothers	Specimen boxes	45.00
28	34	William MacCann	Blankets (horse)	27.00
29	35	Wells, Fargo & Co	Expressage	41.60
30	36	Albion S. Howe	Services, September 1 to 30, 1886	60.00
30	37	Pay-roll	Services, September, 1886	572.40
30	38	G. W. Granniss	Rent of rooms	157.98
30	39	William B. Ross	Blacksmithing	37.50
30	40	H. W. Turner	Field expenditures	85.86
30	41	George Phillips	Services, September 1 to 30, 1886	50.00
30	42	Western Union Telegraph Company.	Transmitting telegrams	8.24
30	43	W. Lindgren	Field expenditures	58.77
30	44	F. C. Boyce	Services, September 1 to 30, 1886	68.00
30	45	R. R. Hawkins	Cash expenditures	46.50
30	46	W. Lindgren	Traveling expenses	49.00
				4,595.07

Abstract of disbursements made by A. O'D. Taylor, jr., special disbursing agent, U. S. Geological Survey, during the third quarter of 1886.

1886.				
Aug. 14	1	A. Prescott Baker	Rent for July	$50.00
14	2	F. E. Swift	Board of party for July	129.50
14	3	J. Eliot Wolff	Traveling expenses	8.48
14	4	William H. Hobbs	......do	8.00
14	5	......do	Miscellaneous supplies	8,75
14	6	Josiah Pierce, jr	Traveling expenses	7.45
14	7	J. Eliot Wolff	Miscellaneous expenses	3.21
17	8	Richard Bliss	Bibliographical work	53.85
17	9	Thomas Coggshall, postmaster	Post-office box-rent	5.00
17	10	W. and L. E. Gurley	Instruments, etc	16.78
17	11	George W. Simmons & Co	Tents, etc	66.75
18	12	Captain B. S. Welville	Board, etc., for T. Nelson Dale	9.27
19	13	Henry M. Steele	Traveling expenses	7.70
21	14	T. Nelson Dale	......do	21.70
25	15	J. H. Flagg	Hire of team, etc., July, 1886	61.00
27	16	Josiah Pierce, jr	Incidental expenses	20.51
27	17	William H. Hobbs	Traveling expenses	14.30
27	18	Gleason Brothers	Groceries for party	20.40
27	19	Charles W. Billings	Hardware supplies	44.08
27	20	Bayard T. Putnam	Traveling expenses	21.84
28	21	Henry M. Steele	Pay, July 1 to 16, 1886	16.00
28	22	Lizzie R. Saunders	Temporary services	10.75
31	23	Bayard T. Putnam	Incidental expenses	26.31
31	24	A. Prescott Baker	Rent for August, 1886	50.00

Abstract of disbursements made by A. O'D. Taylor, etc.—Continued.

Date.	No. of voucher.	To whom paid.	For what paid.	Amount.
1886.				
Aug. 31	25	Edward Stabe	Traveling expenses	$7.75
31	26	Ada F. Crandall	Temporary services	5.25
31	27	Pay-roll	Salaries, August, 1886	924.13
Sept. 4	28	T. Nelson Dale	Traveling expenses	15.13
4	29	Raphael Pumpelly	Incidental	8.75
6	30	Gleason Brothers	Groceries	15.91
6	31	Charles W. Billings	Field supplies	12.19
6	32	J. H. Flagg	Hire of team, etc	184.50
8	33	Adams Express Company	Express charges	6.50
13	34	Raphael Pumpelly	Traveling expenses	107.96
Sept. 20	35	M. A. Dyke	Provisions	19.70
21	36	Bayard T. Putnam	Traveling expenses	44.94
23	37	William McGrath	Horse keep and supplies	68.17
24	38	William H. Hobbs	Traveling expenses	34.40
24	39	T. Nelson Dale	......do	14.57
24	40	William H. Hobbs	Incidental expenses	1.13
Aug. 2	41	J. Eliot Wolff	Traveling expenses	45.23
Sept. 27	42	A. Prescott Baker	Rent for September, 1886	50.00
30	43	Raphael Pumpelly	Traveling expenses	96.42
				2,296.26

Abstract of disbursements made by Anton Karl, special disbursing agent U. S. Geological Survey, during the third and fourth quarters of 1886.

1886.				
Sept. 30	1	Anton Karl	Services, September 1 to 30, 1886	$163.00
Oct. 31	2	T. H. Hines	Transportation	40.32
31	3	Anton Karl	Services, October 1 to 31, 1886	168.50
Nov. 1	4	......do	Services, November 1 to 30, 1886	163.00
Dec. 1	5	......do	Traveling expenses	33.61
16	6	......do	Subsistence and transportation	133.05
16	7	Fessenden N. Chase	Services, November 1 to 22, 1886	36.66
31	8	Anton Karl	Services, December 1 to 31, 1886	168.50
				906.64

Abstract of disbursements made by Alfred M. Rogers, disbursing agent U. S. Geological Survey, during the third quarter of 1886.

1886.				
Aug. 7	1	Chas. Niver	Field supplies and expenses	$18.58
Sept. 1	2	Kerstins & Peters	.....do	3.54
3	3	Chas. Niver	......do	23,19
4	4	Jno. Murphy	......do	5.00
4	5	Daniels & Fisher	Office furniture	3.00
4	6	Miller & Neilson	Office repair	6.25
15	7	Arthur Kelly	Traveling expenses	64.25
15	8	Pacific Express Company	Transportation of property	3.60
15	9	J. T. McAllister	Field supplies and expenses	1.25
15	10	Jno. Thomas	Services, August 24 to 25, 1886	6.00
15	11	Geo. W. Berten	Services, July 5 and 6, 1886	8.00
15	12	J. J. Riethman & Co	Laboratory material	.80
July 31	13	Pay-roll	Salaries, July, 1886	889.90
Aug. 31	14	......do	Salaries, August, 1886	815.70
Sept. 15	15	H. Rosenblat	Office repair	2.50
20	16	C. Whitman Cross	Traveling expenses	19.30
27	17	Peter McCourt	Rent	100.00
30	18	Simons & Simmers	Field supplies and expenses	1.50
30	19	J. T. McAllister	......do	.75
30	20	Andrews & Chambers	Field subsistence	.70
30	21	Pacific Express Company	Transportation of property	1.92
30	22	Simons & Simmers	Field supplies and expenses	5.25
30	23	J. T. McAllister	......do	1.00
30	24	Wise Brothers	......do	4.15
30	25	M. J. Mitchell	Field instruments	2.25
30	26	Wise Brothers	Field supplies, subsistence	12.37
30	27	C. F. Hicks	Field supplies and expenses	5.50
30	28	James Morgan	Office supplies and repairs	1.70
30	29	John Murphy	Field supplies and expenses	11.50
30	30	R. W. Speer, postmaster	Correspondence	2.50
30	31	Geo. N. Young	Field supplies and expenses	36.25

Abstract of disbursements made by Alfred M. Rogers, etc.—Continued.

Date.	No. of voucher.	To whom paid.	For what paid.	Amount.
1886.				
Sept. 30	32	Sam P. Barbee	Rent and supplies and expenses	$160.85
30	33	Chas. Drake	Services, September 28, 1886	.75
30	34	M. Hodges	Services, September 30, 1886	1.50
30	35	Chas. Anderson	......do	12.00
30	36	Wm. Dingle	Office supplies	5.60
30	37	Geo. Linhort	Services and laboratory material	1.50
30	38	H. Z. Salomon	Field subsistence	92.11
30	39	......do	......do	66.91
30	40	......do	......do	56.49
30	41	Geo. H. Eldridge	Traveling expenses	55.05
30	42	S. F. Emmons	......do	47.25
30	43	......do	......do	65.00
30	44	C. Whitman Cross	......do	20.00
30	45	Dan Phillips	Services, July, August, and September, 1886.	13.00
30	46	Adams Express Company	Transportation of property	16.90
30	47	Wells, Fargo & Co.'s Express	......do	.75
30	48	Denver and Rio Grande Express	......do	1.10
30	49	Pacific Express Company	......do	16.35
30	50	Western Union Telegraph Company.	Correspondence	4.89
30	51	Chain, Hardy & Co	Stationery	25.52
30	52	R. J. Spotswood	Services and ranching stock	106.00
30	53	S. F. Emmons	Pay, July 1 to September 30, 1886	1,000.00
30	54	Pay-roll	Services, September, 1886	803.60
				4,583.32

Abstract of disbursements made by John D. McChesney, chief disbursing clerk, U. S. Geological Survey, during the fourth quarter of 1886.

Date.	No. of voucher.	To whom paid.	For what paid.	Amount.
1886.				
Oct. 2	1	Columbus Freeman	Pay, September 1 to October 1, 1886	$86.13
5	2	Washington city post-office	Rent of post-office boxes	8.00
5	3	Washington Gas-light Company	Gas for September, 1886	66.30
5	4	B. F. McCaully	Care and forage of public animals	26.50
5	5	David T. Day	Traveling expenses	25.85
5	6	C. G. Rockwood, jr	Services, September 6 to 11, 1886	48.00
5	7	William Hallock	Salary, September, 1886	130.40
5	8	James G. Bowen	Care and forage of public animals	65.13
5	9	Van H. Manning, jr	Salary, September, 1886	58.80
5	10	M. T. Burns	......do	55.00
5	11	W. E. Horton	......do	50.00
5	12	Laurence Thompson	......do	73.40
5	13	N. Landon Burchell	......do	60.00
5	14	R. H. Phillips	......do	73.40
5	15	W. J. Grambs	......do	73.40
5	16	E. B. Clark	......do	58.80
5	17	William B. Blake	Salary, August 1 to September 15, 1886.	60.00
5	18	Clifford Arrick	Salary, September, 1886	68.40
5	19	Joseph H. Wheat	......do	49.00
5	20	S. A. Aplin	......do	73.40
5	21	Sumner H. Bodfish	......do	163.00
6	22	Pay-roll of employés	Services, September, 1886	187.60
6	23	W. M. Thygeson	Services between September 10 and 30, 1886.	16.50
6	24	C. R. Van Hise	Services between September 1 and 30, 1886.	85.00
6	25	E. J. Hatcher	Services, September 11 to 30, 1886	30.00
6	26	James R. Thompson	Services, between September 13 and 30, 1886.	9.00
6	27	F. S. Hunter	Services, September, 1886	50.00
6	28	William Kramer	......do	50.00
6	29	Frank A. Pierce	Services, August 30 to September 30, 1886.	47.90
6	30	Eugene E. Pierce	Services, September, 1886	50.00
5	31	Pay-roll of employés	......do	737.96
9	32	E. H. King	Repairing office furniture	36.50
7	33	W. H. Dall	Traveling expenses	38.81
12	34	R. B. Cameron	Services, September, 1886	40.00
12	35	Pay-roll of employés	......do	684.62
12	36	Julius Bien & Co	Copies of plates for geological and topographical atlas.	627.80
13	37	James Forrestell	Services, September 28 to 30, 1886	9.00

Abstract of disbursements made by John D. McChesney, etc.—Continued.

Date.	No. of voucher.	To whom paid.	For what paid.	Amount.
1886.				
Oct. 13	38	Robert Hay	Traveling expenses	$65.62
13	39	Asher Atkinson	do	84.70
13	40	William F. Marvine	do	48.83
13	41	N. B. K. Hoffman	do	61.63
13	42	John E. Hill	do	31.03
13	43	P. H. Bevier	do	45.99
13	44	W. H. Luster, jr	do	91.27
13	45	F. W. Bennett	do	94.51
13	46	C. C. Vermeule	Cash paid for stationery, etc	23.70
14	47	John D. McChesney	Traveling expenses	13.00
14	48	H. R. Geiger	do	72.94
14	49	Robert T. Hill	do	91.59
14	50	August Kamm	Repairing aneroid barometer	14.25
14	51	Edward Kübel	Cash paid for repairs to instruments	5.90
15	52	Bailey Willis	Field expenses	123.66
18	53	G. F. Becker	Salary, September, 1886	326.00
19	54	Adams Express Company	Freight charges	195.85
19	55	George W. Knox	Freight charges and hauling	89.95
19	56	Capt. C. E. Dutton	Cash paid for field expenses	139.58
19	57	do	Traveling expenses	141.15
19	58	James W. Queen & Co	Instruments, repairs, etc	749.04
19	59	I. C. Russell	Cash paid for field expenses	209.45
19	60	Henry J. Green	Instruments and repairs	2,150.25
19	61	W. and L. E. Gurley	do	140.00
19	62	do	Odometers	206.00
19	63	J. S. Diller	Traveling expenses	162.38
19	64	Chesapeake and Potomac Telephone Company.	Services, July 1 to September 30, 1886.	155.50
19	65	Nelson H. Darton	Traveling expenses	49.43
19	66	do	do	16.15
19	67	George Ryneal, jr	Artists' material	6.80
19	68	Baltimore and Ohio Railroad Company.	Transportation of assistants	219.65
19	69	Pennsylvania Railroad Company	do	519.51
20	70	Baltimore and Ohio Railroad Company.	Freight	2.63
20	71	De Witt Ramsey	Field material	15.21
20	72	E. H. Barbour	Pay for July, August, and September, 1886.	350.00
20	73	Richard R. Thornton	Washing towels	1.18
20	74	Chesapeake and Ohio Railroad Company.	Transportation of assistants	11.70
20	75	F. S. Hunter	Pay, October 1 to 4, 1886	6.45
19	76	Virginia Midland Railway Company.	Transportation of assistants	17.50
19	77	Northern Pacific Railroad Company.	do	203.60
19	78	do	do	72.10
19	79	Oregon and California Railroad Company.	do	13.18
19	80	Baltimore and Potomac Railroad Company.	do	6.50
21	81	Bailey Willis	Traveling expenses	75.25
21	82	Columbus Freeman	do	21.80
22	83	Nat. Tyler, jr	Services, August 21 to 31, 1886	17.74
22	84	do	Services, September, 1886	50.00
22	85	A. C. Peale	Traveling expenses	82.65
22	86	F. V. Hayden	do	65.25
22	87	M. P. Felch	Pay for September, 1886	170.00
22	88	Wyckoff, Seamans & Benedict	Office furniture, repairs, etc	40.97
23	89	Thomas M. Chatard	Traveling expenses	231.00
23	90	Frank Burns	do	6.75
26	91	Nelson H. Darton	do	93.21
26	92	Warren Upham	do	266.96
26	93	W. J. McGee	do	13.91
26	94	R. D. Salisbury	do	232.91
26	95	P. D. Staats	do	61.30
26	96	H. Mayhew	Subsistence supplies	24.04
27	97	National Press Intelligence Company.	Services and publication	13.65
27	98	Z. D. Gilman	Laboratory and photographic material.	185.05
27	99	Quartermaster's Department, U. S. Army.	1 post flag	9.95
27	100	D. J. Howell	Field expenses	105.00
31	101	L. Drury	Services, July 22 to August 22, 1886	255.00
31	102	Roland D. Irving	Salary, October, 1886	252.70
31	103	Lawrence C. Johnson	do	117.90
31	104	O. C. Marsh	do	387.00

Abstract of disbursements made by John D. McChesney, etc.—Continued.

Date.	No. of voucher.	To whom paid.	For what paid.	Amount.
1886.				
Oct. 31	105	William M. Fontaine	Salary, October, 1886	$168.50
31	106	J. Henry Blake	......do	151.60
31	107	Marcus Baker	......do	202.20
31	108	F. V. Hayden	......do	337.00
31	109	C. W. Hawkins	......do	50.00
31	110	Frank Burns	......do	75.80
31	111	Pay-roll of employés	Services, October, 1886	707.08
31	112	Ira Sayles	Salary, October, 1886	202.20
31	113	Fessenden N. Chase	......do	50.00
31	114	George W. Shutt	......do	252.70
31	115	Pay-roll of employés	Services, October, 1886	874.30
31	116	......do	......do	3,275.90
31	117	......do	......do	1,602.60
31	118	......do	......do	890.30
31	119	......do	......do	3,093.13
31	120	......do	......do	939.87
30	121	H. L. Hinkle & Bro	19 tons white ash coal	91.01
30	122	John C. Robertson	Traveling expenses	10.25
30	123	......do	......do	7.95
30	124	J. E. Todd	Services during September, 1886	75.00
30	125	W. N. Merriam	Salary, September and October, 1886	232.10
30	126	T. C. Chamberlin	Salary, October, 1886	308.30
30	127	J. Belknap Marcou	......do	101.10
29	128	A. C. Peale	Cash paid for field expenses	58.07
29	129	......do	Traveling expenses	10.50
31	130	George P. Merrill	......do	92.80
31	131	Leo Lesquereux	Salary, October, 1886	75.00
31	132	Samuel H. Scudder	......do	210.60
31	133	H. R. Geiger	......do	126.40
31	134	F. W. Geiger	......do	30.00
31	135	H. F. Walling	......do	168.50
31	136	A. C. Peale	Traveling expenses	42.55
Nov. 1	137	Robert Hay	Salary, October, 1886	75.00
2	138	Bailey Willis	......do	202.20
3	139	James G. Bowen	Care and forage of public animals	68.00
3	140	B. F. McCaully & Co	......do	26.50
3	141	Lester F. Ward	Traveling expenses	17.66
3	142	Washington Gas-light Company	Gas for October, 1886	70.39
3	143	N. S. Shaler	Salary, October, 1886	260.00
3	144	Paul Morrison	Services, August 16 to October 18, 1886	127.00
3	145	James W. Queen & Co	Slide boxes	14.00
3	146	Morrison & McGregor	Subsistence, supplies, etc	38.30
3	147	Great Falls Ice Company	Ice during July, August, and September, 1886.	47.94
3	148	W. S. Bayley	Services during October, 1886	40.00
3	149	Peter Kadonce	Services from August 16 to October 18, 1886.	128.00
3	150	C. H Oppel & Sons	Subsistence supplies, etc	100.71
3	151	Pennsylvania Railroad Company	Transportation of assistants	6.50
3	152	Atlantic Coast Line Railroad Company.	......do	33.00
3	153	L. P. Bush	Services, October, 1886	50.00
3	154	Joseph Brown	Services, July 22 to October 22, 1886.	120.00
3	155	G. Baur	Services, October, 1886	140.00
3	156	H. Gibbs	......do	60.00
3	157	J. S. Topham	Collecting bags	7.00
3	158	Pay-roll of employés	Services, October, 1886	264.80
3	159	C. A. White	Traveling expenses	171.15
4	160	William Noell	......do	20.75
4	161	J. Loring Whittington	Stationery, etc	16.76
4	162	William P. Trowbridge, jr	Traveling expenses	31.05
4	163	I. C. Russell	......do	29.05
4	164	......do	......do	4.45
4	165	Henry J. Biddle	......do	28.75
4	166	William Hallock	Salary, October, 1886	134.80
4	167	Pay-roll of employés	Services, October, 1886	710.60
5	168	......do	......do	383.70
5	169	M. J. Des Forges	Publications	4.00
5	170	W. J. McGee	Traveling expenses	10.33
5	171	Charles S. Cudlip	Photographic supplies	102.89
6	172	John C. Parker	Publications	11.50
8	173	H. R. Geiger	Traveling expenses	81.56
9	174	Charles W. Howell	Services, October, 1886	60.00
9	175	Baltimore and Potomac Railroad Company.	Freight	6.33
9	176	James R. Thompson	Services during October, 1886	26.00
9	177	M. P. Felch	Pay, October, 1886	170.00
9	178	W. P. Rust	Services, October, 1886	130.00
9	179	Charles D. Walcott	......do	168.50
9	180	Frank Leverett	Traveling expenses	71.24

Abstract of disbursements made by John D. McChesney, etc.—Continued.

Date.	No. of voucher.	To whom paid.	For what paid.	Amount.
1886.				
Nov. 10	181	William H. Butler	Office supplies	$9.65
10	182	Hume, Cleary & Co	......do	8.25
10	183	I. C. Russell	Cash paid for field expenses	67.73
11	184	C. C. Vermeule	Cash paid for stationery	26.87
11	185	..... do	Traveling expenses	55.51
11	186	N. S. Shaler	......do	255.55
11	187	F. W. Bennett	..... do	75.68
11	188	George H. Williams	......do	254.60
11	189	J. H. D. Baker	Subsistence supplies, etc	13.25
11	190	C. R. Van Hise	Services during October, 1886	88.75
11	191	National Press Intelligence Company.	Services and publications	4.20
11	192	Memphis and Little Rock Railroad Company.	Transportation of assistants	58.00
12	193	Robert T. Hill	Traveling expenses	89.16
12	194	......do	......do	55.41
13	195	W. Beck	Pay, September 1 to October 31, 1886.	220.00
13	196	Fred. Brown	......do	180.00
13	197	Whitall, Tatum & Benedict	Laboratory supplies	29.18
13	198	E. H. King	Office desk	80.00
13	199	Becker Bros	Laboratory material	30.00
13	200	Charles H. Kraft	Laboratory supplies	133.50
13	201	J. & H. Berge	Laboratory material	27.31
13	202	J. Bishop & Co	......do	60.92
13	203	C. G. Rockwood, jr	Traveling expenses	23.82
13	204	J. S. Diller	......do	345.84
13	205	W. H. Luster, jr	......do	77.17
15	206	Robert Leitch & Son	Laboratory supplies	34.30
15	207	P. H. Bevier	Traveling expenses	65.61
15	208	Robert Hay	......do	75.64
15	209	N. B. K. Hoffman	......do	38.51
15	210	W. F. Marvine	......do	46.50
15	211	L. H. Schneider's Son	Office material and supplies	53.72
15	212	Oregon Railway and Navigation Company.	Transportation of assistants	16.18
15	213	John J. Lennon	Services, October 4 to November 6, 1886.	150.00
15	214	John Morrison	Services, October 5 to November 8, 1886.	69.00
15	215	N. M. Thygeson	Services during October, 1886	33.00
16	216	L. S. Baldwin, jr	Traveling expenses	31.25
16	217	......do	......do	5.25
16	218	Charles D. Walcott	......do	336.00
16	219	C. T. Reid	......do	40.25
13	220	Emil Jonscher	Office material	6.40
16	221	Mutual District Messenger Company.	Rent of night watch, July 1 to October 31, 1886.	20.00
17	222	Kansas City, Saint Joseph and Council Bluffs Railway Company.	Transportation of assistants	17.15
17	223	Oregon and California Railroad Company.	......do	54.72
17	224	Ohio and Mississippi Railway Company.	......do	20.25
17	225	Atlantic and Pacific Railroad Company.	......do	33.70
17	226	......do	......do	34.35
17	227	......do	......do	53.35
17	228	Northern Pacific Railroad Company.	......do	197.00
17	229	P. D. Staats	Traveling expenses	89.52
17	230	Asher Atkinson	......do	105.50
17	231	Walker, Evans & Cogswell	2 maps of South Carolina	18.00
17	232	Jayne & Chase	Laboratory supplies	11.58
18	233	Ira M. Buell	Traveling expenses	67.46
18	234	J. E. Todd	......do	71.96
18	235	David Carriboo	Services, September 4 to November 8, 1886.	132.00
19	236	William B. Lane	Traveling expenses	28.60
19	237	Union Stone Company	Laboratory supplies	16.87
18	238	George A. Leavitt & Co	Publications	3.00
19	239	W. H. Porter, agent	Repairing caligraph	4.50
23	240	Sumner H. Bodfish	Salary, July, 1886	168.50
23	241	H. F. Walling	......do	168.50
23	242	John H. Stark	Making 1 catalogue case	9.00
23	243	Buffalo Dental Manufacturing Company.	Laboratory material	15.00
23	244	Ira Sayles	Traveling expenses	219.75
23	245	Charles S. Cudlip	Photographic supplies	187.84

Abstract of disbursements made by John D. McChesney, etc.—Continued.

Date.	No. of voucher.	To whom paid.	For what paid.	Amount.
1886.				
Nov. 23	246	J. E. Todd	Services during October, 1886	$30.00
24	247	Royce & Marean	Instruments and repairs	2.25
24	248	David T. Day	Traveling expenses	9.25
26	249	T. C. Chamberlin	do	162.56
26	250	Clarence E. Dutton	do	115.50
26	251	Z. D. Gilman	Office and photographic supplies	186.79
26	252	Frank Tweedy	Traveling expenses	51.70
26	253	J. Belknap Marcou	do	65.12
30	254	Ira Sayles	Salary, November, 1886	195.60
30	255	Pay-roll of employés	do	690.65
30	256	C. W. Hawkins	do	50.00
27	257	Ed. C. Ryan	Traveling expenses	46.00
30	258	do	Salary, November, 1886	50.00
30	259	B. H. Colgrove	do	50.00
30	260	James E. Shelley	do	50.00
30	261	Charles F. Urquhart	do	70.00
30	262	E. T. Perkins, jr	do	73.40
30	263	William M. Fontaine	do	163.00
30	264	F. V. Hayden	do	326.00
30	265	O. C. Marsh	do	326.00
30	266	W. S. Bayley	Services during November, 1886	40.00
30	267	J. Henry Blake	Salary, November, 1886	146.80
30	268	Roland D. Irving	Services during November, 1886	244.60
30	269	Coates & Freeman	Hire of wagon and team	18.00
30	270	Sam H. Scudder	Salary, November, 1886	203.80
30	271	Samuel Lewis & Sons	Laboratory supplies	55.35
30	272	Pay-roll of employés	Services, November, 1886	407.60
30	273	do	do	794.20
30	274	C. A. White	Traveling expenses	22.50
30	275	Z. D. Gilman	Laboratory supplies	14.62
30	276	D. J. Howell	Cash paid for board, lodgings, etc	101.40
30	277	H. F. Walling	Services, November, 1886	163.00
30	278	Pay-roll of employés	do	2,395.00
30	279	do	do	3,963.80
30	280	do	do	2,998.73
30	281	do	do	1,543.00
30	282	do	do	964.60
30	283	do	do	846.40
30	284	George W. Shutt	do	244.60
30	285	F. W. Geiger	do	30.00
30	286	Leo Lesquereux	do	75.00
30	287	H. R. Geiger	Salary, November, 1886	122.20
30	288	John C. Robertson	Services, September 1 to October 27, 1886.	93.55
30	289	C. T. Reid	Services, November 1 to 30, 1886	50.00
Dec. 2	290	Thomas C. Basshaw & Co	Laboratory supplies	75.08
Nov. 30	291	James E. Shelley	Traveling expenses	18.20
30	292	Wm. J. Peters	do	60.50
30	293	Wm. H. Herron	do	31.25
30	294	Geo. T. Hawkins	do	79.30
30	295	E. T. Perkins, jr	do	42.50
Dec. 2	296	Western Union Telegraph Company.	Telegrams, July, August, September, October, 1886.	71.22
2	297	Washington Gas-light Company	Gas for November, 1886	95.65
2	298	James G. Bowen	Care and forage of public animals	64.70
2	299	T. C. Chamberlin	Services, November, 1886	293.40
2	300	Robert Hay	do	75.00
2	301	Frank Leverett	Services, September 1 to November 26, 1886.	225.00
2	302	Adams Express Company	Freight charges, September, 1886	84.55
2	303	do	Freight charges, October, 1886	75.75
3	204	B. F. McCaully & Co	Care and forage of public animals	26.50
3	305	D. McClelland	For township blanks	16.00
3	306	Wyckoff, Seamans & Benedict	Office furniture, supplies and repairs	199.04
3	307	H. L. Hinkle & Bro	Fuel	148.49
3	308	E. H. King	Office furniture	37.00
4	309	Redick H. McKee	Traveling expenses	120.25
4	310	J. Edward Whitfield	do	9.75
4	311	H. M. Wilson	Cash paid for field expenses	50.00
4	312	F. S. Somner	Services, November 1 to 12, 1886	31.50
4	313	Baltimore and Potomac Railroad Company.	Freight charges.	1.13
4	314	Jas. E. Shelley	Traveling expenses	34.45
4	315	James S. Merritt	do	102.75
4	316	Fred. W. Pilling	Supplies and services	102.37
6	317	Ira Sayles	Traveling expenses	117.13
6	318	N. S. Shaler	Salary, November, 1886	260.00
6	319	National Press Intelligence Company.	Newspaper clippings	2.85

Abstract of disbursements made by John D. McChesney, etc.—Continued.

Date.	No. of voucher.	To whom paid.	For what paid.	Amount.
1886.				
Dec. 7	320	W. N. Merriam	Services, November, 1886	$114.20
7	321	Thomas Watson	Services, October 22 to 31, 1886	20.00
7	322	Warren Upham	Services, September 1 to November 30, 1886.	296.70
7	323	Clarence Dutton, jr	Services, October 1 to November 30, 1886.	78.00
7	324	H. M. Wilson	Traveling expenses	131.50
7	325	J. W. Goodell	Hauling and preparing specimens for shipment.	10.00
8	326	Jno. H. Renshawe	Services, October, 1886	210.60
8	327	Charles Catlett	Services, November 8 to December 2, 1886.	49.87
9	328	J. Loring Whittington	Stationery	10.50
9	329	C. C. Vermeule	Traveling expenses	42.11
9	330	......do	Cash paid for services, etc	30.47
9	331	Quartermaster's Department, U. S. Army.	Forage	33.34
9	332	S. A. Aplin	Traveling expenses	14.80
9	333	F. W. Bennett	......do	75.49
9	334	James Beggs & Co	Laboratory material	56.50
9	335	Wm. M. Hughes	Care and feed of public animals	20.00
9	336	R. H. Chapman	Traveling expenses	84.00
10	337	Arthur P. Davis	......do	90.25
10	338	Pay-roll of employés	Services, November, 1886	698.80
10	339	C. E. Beecher	Drawings	21.00
10	340	Hart & Von Arx	......do	96.00
10	341	Baltimore and Potomac Railroad Company.	Freight charges	1.24
10	342	Earle Sloan	Services, September and October, 1886.	200.00
10	343	J. B. Hatcher	Pay, July 1 to October 31, 1886	900.00
10	344	H. Gibb	Pay, November, 1886	60.00
10	345	G. Baur	......do	140.00
10	346	J. B. Hatcher	......do	150.00
10	347	L. P. Bush	......do	50.00
11	348	Lawrence C. Johnson	......do	114.20
11	349	Henry J. Biddle	......do	50.00
11	350	Claud Van Bibber	Laboratory material	87.63
11	351	M. P. Felch	Services, November, 1886	170.00
11	352	Clifford Arrick	Traveling expenses	29.72
11	353	......do	Miscellaneous field expenses	66.75
11	354	A. H. Chase & Co	Cleaning carpets	3.04
11	355	Chicago, Milwaukee and St. Paul Railroad Company	Transportation of assistants	29.00
13	356	Paul Holman	Traveling expenses	62.50
13	357	Ira Sayles	......do	129.70
14	358	Wm. F. Marvine	......do	41.75
14	359	N. B. K. Hoffman	......do	39.34
14	360	W. H. Luster, jr	......do	70.38
14	361	Asher Atkinson	......do	87.65
14	362	Mark B. Kerr	......do	123.17
14	363	......do	Cash paid for field expenses	769.57
15	364	R. H. Chapman	......do	37.60
15	365	Eugene Ricksecker	......do	403.93
15	366	Eric M. Noble	Services, November 11 to December 11, 1886.	58.00
15	367	L. H. Phillips	Pasturage	49.50
15	368	P. D. Staats	Traveling expenses	72.18
15	369	P. H. Bevier	......do	73.54
16	370	H. M. Wilson	Cash paid for field expenses	233.71
16	371	A. H. Thompson	Traveling expenses	133.90
16	372	......do	......do	133.75
17	373	A. F. Dunnington	Cash paid for field expenses	178.95
17	374	E. B. Clark	Traveling expenses	19.95
17	375	M. T. Burns	......do	19.95
17	376	Nathaniel Tyler	......do	17.13
18	377	Van H. Manning, jr	......do	43.77
18	378	W. J. Grambs	Miscellaneous expenses	79.38
18	379	......do	Traveling expenses	16.73
18	380	W. E. Horton	......do	11.70
18	381	Gustav E. Stechert	Publications	85.00
18	382	Laurence Thompson	Traveling expenses	15.80
20	383	Basil Duke	......do	24.25
20	384	E. B. Clark	Miscellaneous field expenses	56.50
21	385	S. H. Bodfish	Traveling expenses	34.15
21	386	......do	......do	17.45
21	387	Robert D. Cummin	......do	16.05
22	388	Van H. Manning, jr	......do	79.86

Abstract of disbursements made by John D. McChesney, etc.—Continued.

Date.	No. of voucher.	To whom paid.	For what paid.	Amount.
1886.				
Dec. 22	389	David T. Day	Traveling expenses	$2.25
23	390	W. J. Grambs	Miscellaneous field expenses	22.08
23	391	Laurence Thompson	......do	138.40
23	392	W. J. Grambs	Traveling expenses	6.79
24	393	Robert Boyd	Office and laboratory supplies	87.64
24	394	H. L. Hinkle & Bro	Fuel	191.60
27	395	Sumner H. Bodfish	Miscellaneous field expenses	143.74
28	396	A. P. Anderson	Pasturage	12.00
28	397	J. C. Pierce	Storage	3.00
28	398	Charles C. Bassett	Traveling expenses	13.30
29	399	William F. Lutz	Office supplies	1.25
29	400	E. W. F. Natter	Miscellaneous field expenses.	23.87
29	401	......do.	......do	26.00
29	402	......do.	......do	129.85
30	403	Robert Robertson	Traveling expenses	13.75
31	404	N. S. Shaler	Services, December, 1886	270.00
31	405	E. H. King	Tank for laboratory	50.00
31	406	W. E. Horton	Services	50.00
31	407	Willard D. Johnson	Miscellaneous field expenses	241.85
31	408	Pay-roll of employés	Services, December, 1886	551.04
31	409	C. R. Van Hise	Services, November 1 to December 31, 1886.	175.00
31	410	Lawrence C. Johnson	Salary, December, 1886	117.90
31	411	O. C. Marsh	......do	337.00
31	412	William M. Fontaine	......do	168.50
31	413	N. M. Thygeson	Services	42.24
31	414	W. N. Merriam	Services, December, 1886	117.90
31	415	W. S. Bayley	......do	40.00
31	416	Arthur P. Davis	Cash paid for field expenses	86.00
31	417	Robert Hay	Traveling expenses	16.45
31	418	Edward Kübel	Cash paid for repairs to instruments.	7.96
31	419	E. H. Sargent	Services, December, 1886	50.00
31	420	J. Henry Blake	Salary, December, 1886	151.60
31	421	Leo Lesquereux	......do	75.00
31	422	H. R. Geiger	......do	126.40
31	423	Samuel H. Scudder	......do	210.60
31	424	William P. Rust	......do	119.25
31	425	L. H. Phillips	Pasturage	44.00
31	426	H. F. Walling	Salary, December, 1886	168.50
31	427	Pay-roll of employés	Services, December, 1886	309.67
31	428	James G. Bowen	Care and forage of public animals	57.75
31	429	Pay-roll of employés	Services, December, 1886	874.30
31	430	......do	......do	995.70
31	431	......do	......do	4,345.30
31	432	......do	......do	3,059.43
31	433	......do	......do	2,085.30
31	434	......do	......do	1,485.70
31	435	......do	......do	2,354.17
31	436	George W. Shutt	......do	262.70
31	437	Kalamazoo Railroad Velocipede	Instruments	65.00
31	438	Amos Scott	Services, October 24 to November 30, 18-6.	75.48
31	439	......do	Services, December, 1886	60.00
31	440	Washington City post-office	Rent of post-office boxes	8.00
31	441	J. E. Todd	Services during November, 1886	25.00
31	442	Roland D. Irving	Traveling expenses	33.57
31	443	D. J. Howell	Field expenses	9.06
31	444	J. S. Newberry	Salary, July 1 to October 10, 1886	997.83
31	445	W. N. Merriam	Traveling expenses	585.19
				87,491.57

SALARIES, OFFICE OF THE DIRECTOR.

Date.	No. of voucher.	To whom paid.	For what paid.	Amount.
1886.				
Oct. 31	1	Thomas J. Ryder	Salary for October, 1886	84.20
31	2	Pay-roll of employés	Services for October, 1886	2,848.40
Nov. 30	3	..... do	Services, November, 1886	2,839.80
Dec. 31	4	......do	Services, December, 1886	2,964.59
				8,736.99

Abstract of disbursements made by H. C. Rizer, disbursing agent, U. S. Geological Survey, during the fourth quarter of 1886.

Date.	No. of voucher.	To whom paid	For what paid.	Amount.
1886.				
Oct. 6	1	Adamson & Burbage	Field subsistence	$100.62
8	2	W. H. Powell	Services, July 15 to 31	30.15
8	3	......do	Traveling expenses	15.10
8	4	A. F. Dunnington	Field expenses	74.97
8	5	William Armbruster	Labor	21.00
8	6	A. & B. Schuster	Subsistence	29.54
8	7	J. J. Clawson	Services, July 21 to 31	6.77
8	8	Merrill Willis	Services, September 1 to 19	9.50
9	9	Charles A. Garlick	Field expenses	42.50
9	10	H. M. Wilson	......do	58.05
11	11	A. F. Dunnington	......do	43.64
11	12	Redick H. McKee	......do	55.90
16	13	E. M. Douglas	......do	88.12
16	14	Frank Tweedy	Services, August 1 to 15	48.91
16	15	......do	Field expenses	5.00
Sept. 30	16	Pay-roll	Services, September	314.20
30	17	......do	......do	730.90
Oct. 16	18	R. N. Johnson	Services, August 16 to 31	25.80
16	19	James S. Merritt	Services, August 24 to September 30	62.90
16	20	H. S. Wallace	Field expenses	91.30
16	21	......do	......do	36.25
18	22	Charles H. Fitch	......do	28.30
18	23	Thomas W. Brookbank	Field material	31.05
18	24	B. H. Gilman	Forage	27.69
22	25	A. F. Dunnington	Field expenses	26.70
22	26	Redick H. McKee	......do	29.00
31	27	Pay-roll	Services, October	447.54
31	28	......do	......do	268.83
20	29	C. E. Dutton, jr	Services, August 1 to September 30	80.00
22	30	A. H. Thompson	Traveling expenses	125.15
22	31	......do	......do	105.80
22	32	A. M. Boyer	Board	5.00
22	33	Jeremiah Hatch	Subsistence	12.50
22	34	Franklin Willis	......do	10.51
22	35	William H. Solomon	Labor	4.00
22	36	E. M. Douglas	Field expenses	77.40
22	37	Banse & French	Subsistence	63.05
22	38	Burnaham & George	Labor	19.38
22	39	R. U. Goode	Field expenses	80.65
22	40	......do	......do	69.50
22	41	......do	......do	44.97
22	42	......do	Traveling expenses	12.75
31	43	Pay-roll	Services, October	406.60
31	44	......do	......do	288.50
31	45	......do	......do	271.75
31	46	G. A. Johnson	Services, October 6 to 31	33.54
28	47	C. H. Stone	Traveling expenses	53.95
28	48	James S. Merritt	......do	26.65
28	49	......do	......do	51.03
28	50	E. M. Douglas	Field expenses	42.15
28	51	A. Lamme & Co	Subsistence	56.36
28	52	Arthur P. Davis	Services, August 1 to 15	65.22
28	53	......do	Field expenses	36.60
31	54	Pay-roll	Services, October	755.15
29	55	W. H. Leffingwell	Services, August 16 to 31	69.57
29	56	......do	Traveling expenses	54.55
31	57	Pay-roll	Services, October	388.53
30	58	W. H. Leffingwell	Field expenses	18.37
31	59	Pay-roll	Services, October	241.25
30	60	J. S. Diller	Services, September 1 to 30	146.80
31	61	Ed. C. Ryan	Services, October 1 to 31	50.00
31	62	A. P. Davis	Field expenses	20.45
Nov. 1	63	Charles H. Fitch	......do	65.75
1	64	......do	......do	90.02
1	65	R. U. Goode	......do	102.65
4	66	H. S. Wallace	......do	31.25
5	67	W. H. Leffingwell	......do	13.86
5	68	Frank Tweedy	......do	19.40
Oct. 31	69	Pay-roll	Salaries, October	310.47
Nov. 5	70	Lesser & Sawyer	Field supplies	21.80
5	71	Charles A. Garlick	Field expenses	22.12
6	72	A. P. Davis	......do	131.19
8	73	H. M. Wilson	......do	218.50
8	74	Paul Holman	Services, October 1 to 31	70.80
9	75	D. H. Campbell	Services, November 1 to 7	7.00
12	76	R. H. Chapman	Traveling expenses	34.45
12	77	B. H. Gilman	Subsistence	43.67
12	78	......do	Forage	11.19
12	79	A. H. Thompson	Services, October 1 to 31	227.40

Abstract of disbursements made by H. C. Rizer, etc.—Continued.

Date.	No. of voucher.	To whom paid.	For what paid.	Amount.
1886.				
Nov. 13	80	Charles H. Fitch	Traveling expenses	$64.20
13	81	Edward A. Oyster	......do	63.90
15	82	R. U. Goode	......do	99.50
17	83	J. W. Weatherington	Services, October 1 to 31	25.00
17	84	H. S. Wallace	Field expenses	28.60
15	85	Pay-roll	Services, November	40.00
17	86	B. H. Colgrove	Traveling expenses	61.75
19	87	H. S. Wallace	......do	65.60
19	88	Charles F. Urquhart	......do	65.75
19	89	Pay-roll	Services, September	374.20
19	90	Eugene Ricksecker	Services, October 1 to 31	117.90
20	91	Atlantic and Pacific Railroad Company.	Freight	15.84
20	92	E. M. Douglas	Traveling expenses	7.35
20	93	......do	......do	55.60
22	94	R. N. Johnson	......do	88.15
22	95	......do	......do	89.60
27	96	E. C. Landers	Forage	135.00
27	97	Charles A. Garlick	Services, November 1 to 7	14.00
30	98	Paul Holman	Services, November 1 to 30	68.40
27	99	Mark B. Kerr	Services, October 1 to 31	134.80
27	100	Hamilton S. Wallace	Field expenses	9.35
27	101	Eugene Ricksecker	Traveling expenses	129.40
29	102	Alpha Hassler	......do	69.10
29	103	......do	......do	5.95
29	104	A. F. Dunnington	......do	116.75
30	105	H. C. Rizer	Services, October 1 to November 30.	298.40
30	106	Western Union Telegraph Company.	Nine messages	3.08
30	107	R. H. Chapman	Services, November 1 to 30	81.60
				10,285.20

Abstract of disbursements made by P. H. Christie, special disbursing agent, U. S. Geological Survey, during the fourth quarter of 1886.

Date.	No. of voucher.	To whom paid.	For what paid.	Amount.
1886.				
Oct. 27	1	P. H. Christie	Miscellaneous field expenses	$1,310.29
31	2	Pay-roll	Services, October, 1886	523.40
31	3	......do	......do	566.40
31	4	......do	......do	173.53
31	5	......do	......do	490.60
31	6	......do	......do	576.40
31	7	......do	......do	488.00
31	8	......do	......do	569.80
31	9	S. Herbert Geisy	Services, October 1 to 15, 1886	24.46
31	10	John W. Catlett	Services, October 1 to 31, 1886	25.00
31	11	V. T. Carmichael	......do	25.00
31	12	L. S. Woodward	......do	25.00
31	13	James Lewis Howe	......do	25.00
31	14	P. H. Christie	......do	151.60
31	15	Mary Wilder	Services, October 1 to 5, 1886	4.08
31	16	Pay-roll	Services, October, 1886	629.90
31	17	W. F. Fling	Forage of stock	9.80
31	18	J. B. Supeler	......do	11.53
31	19	C. E. Sullivan	Traveling expenses	27.40
31	20	R. C. Dunn	......do	25.55
31	21	S. S. Gannett	......do	15.70
31	22	S. Herbert Geisy	......do	7.30
31	23	James A. Maher	......do	6.60
Nov. 4	24	W. T. Griswold	......do	17.95
4	25	S. S. Gannett	Miscellaneous field expenses	83.85
4	26	Fred J. Knight	......do	58.80
4	27	W. T. Griswold	......do	59.28
4	28	Morris Bien	......do	197.68
4	29	L. C. Fletcher	......do	85.54
4	30	......do	......do	97.45
4	31	......do	......do	57.27
4	32	......do	......do	89.72
4	33	Louis Nell	......do	50.94
4	34	......do	......do	108.54
4	35	......do	......do	48.60
4	36	......do	......do	41.85
5	37	W. T. Griswold	......do	26.88
5	38	......do	......do	49.00
5	39	......do	......do	48.23

Abstract of disbursements made by P. H. Christie, etc.—Continued.

Date.	No. of voucher.	To whom paid.	For what paid.	Amount.
1886.				
Nov. 5	40	W. T. Griswold	Miscellaneous field expenses	$69.84
5	41	do	Traveling expenses	30.18
6	42	Charles M. Yeates	Miscellaneous field expenses	389.32
8	43	Fred P. Gulliver	Traveling expenses	29.65
20	44	do	Services, November 1 to 4, 1886	6.66
20	45	Charles M. Yeates	Miscellaneous field expenses	174.01
20	46	do	Traveling expenses	19.55
20	47	R. Lee Longstreet	do	19.10
20	48	A. E. Wilson	do	19.10
20	49	W. L. Miller	do	19.10
20	50	Edmunds Kennedy	do	6.00
20	51	Henry S. Selden	do	6.75
20	52	H. T. Irwin	do	9.65
20	53	W. E. Lackland	do	8.20
20	54	L. Sandford	do	8.25
20	55	Charles E. Cooke	do	17.55
20	56	Edwin Thomas	do	21.30
20	57	Samuel A. Foot	do	26.70
20	58	W. R. Atkinson	do	26.70
20	59	Jeremiah Ahern	do	26.70
20	60	A. E. Murlin	do	26.70
20	61	C. J. Akin	do	26.70
20	62	Hersey Monroe	do	26.70
20	63	L. D. Brent	do	24.85
20	64	C. W. Goodlove	do	24.35
20	65	M. J. Holt	do	25.10
20	66	R. M. Towson	do	39.75
20	67	Louis Nell	Miscellaneous field expenses	85.45
20	68	do	do	102.30
20	69	V. T. Carmichael	Services, November 1 to 15, 1886	12.50
20	70	L. S. Woodward	Services, November 1 to 10, 1886	8.33
22	71	E. W. Nichols	Services	10.00
22	72	John Boler	Services, November 1 to 16, 1886	16.00
22	73	Shack Smith	do	21.33
22	74	L. J. Allen	do	16.00
22	75	Edwin L. Thomas	Services, November 1 to 13, 1886	13.00
22	76	H. D. Austin	Services, November 1 to 19, 1886	25.33
22	77	E. P. Lane	Traveling expenses	23.25
22	78	John Bolet	do	17.75
22	79	H. D. Austin	do	23.25
22	80	W. M. Edelen	do	23.25
22	81	R. O. Gordon	do	5.75
22	82	W. J. O'Connell	do	8.95
22	83	L. C. Fletcher	do	13.35
22	84	L. J. Allen	do	17.75
22	85	Shack Smith	do	17.75
22	86	H. B. Blair	do	37.40
22	87	R. H. Stuart	do	19.05
23	88	L. C. Fletcher	Miscellaneous field expenses	141.15
26	89	Louis Nell	do	39.25
30	90	Pay-roll	Services, November, 1886	3,279.60
30	91	E. P. Lane	Services, November 1 to 19, 1886	25.33
30	92	Jarvis Amigh	Traveling expenses	7.75
30	93	R. McC. Michler	do	23.00
30	94	M. Hackett	do	25.60
30	95	J. W. Hays	do	19.10
30	96	Louis Nell	do	45.25
30	97	Charles M. Yeates	do	21.10
30	98	W. M. Edelen	Services, November 1 to 19, 1886	31.66
30	99	Gaston Brown	Services, November 1 to 10, 1886	10.00
30	100	M. B. Harralson	Services, November 1 to 19, 1886	25.33
30	101	F. B. Hays	Services, November 1 to 11, 1886	20.00
30	102	Charles Barnitz	Services, November 1 to 6, 1886	10.00
30	103	L. Morgan	Services, November 1 to 3, 1886	4.00
30	104	Isaac S. Hawkins	do	3.00
30	105	Jacob Jankins	do	1.00
30	106	Frank M. Pearson	Miscellaneous field expenses	406.22
30	107	do	Traveling expenses	27.65
30	108	Charles M. Yeates	Miscellaneous field expenses	39.50
30	109	D. C. Harrison	Traveling expenses	48.35
30	110	James Longstreet, jr	do	38.65
30	111	R. H. Hooe	do	6.75
Dec. 6	112	R. C. McKinney	do	61.95
6	113	W. E. Lackland	do	8.85
6	114	Morris Bien	do	22.85
6	115	do	do	9.65
6	116	Gilbert Thompson	do	66.30
6	117	Gaston Brown	do	3.90
9	118	Charles Barnitz	do	16.85
9	119	M. Hackett	Miscellaneous field expenses	44.80

Abstract of disbursements made by P. H. Christie, etc.—Continued.

Date.	No. of voucher.	To whom paid.	For what paid.	Amount.
1886. [illegible]	120	Louis Nell	Miscellaneous field expenses	$102.38
[illegible]	121	Fred J. Knight	Traveling expenses	88.60
[illegible]	122	E. P. Lane	Miscellaneous field expenses	49.40
[illegible]	123	Fred J. Knight	......do	256.59
[illegible]	124	Morris Bien	......do	289.52
[illegible]	125	L. Morgan	Traveling expenses	28.95
[illegible]	126	E. M. Nettleton	Forage of stock	48.33
[illegible]	127	Desha Breckenridge	Traveling expenses	42.95
[illegible]	128	J. B. Supeler	Forage of stock	42.00
[illegible]	129	W. F. Fling	......do	102.98
[illegible]	130	E. M. Harnsberger	......do	59.83
[illegible]	131	N. B. Dunn	......do	278.10
[illegible]	132	E. M. Nettleton	......do	50.00
[illegible]	133	Z. N. Lockhart	Hire of transportation	29.75
[illegible]	134	Gilbert Thompson	Traveling expenses	60.00
[illegible]	135	Pay-roll	Services, December, 1886	3,317.70
[illegible]	136	Baker & Hall	Rent of storage	16.67
				17,862.61

Abstract of disbursements made by John H. Renshawe, disbursing agent, U. S. Geological Survey, during the fourth quarter of 1886.

Date.	No. of voucher.	To whom paid.	For what paid.	Amount.
[illegible]	1	Herbert B. Taylor	Services, September 1 to 30, 1886	$50.00
[illegible]	2	Fred Hoover	1 horse	100.00
[illegible]	3	William J. Peters	Field expenses	54.25
[illegible]	4	John H. Renshawe	......do	217.34
[illegible]	5	......do	Traveling expenses	11.05
[illegible]	6	......do	......do	41.90
[illegible]	7	William J. Peters	Field expenses	68.85
[illegible]	8	......do	......do	26.50
[illegible]	9	H. L. Baldwin, jr	......do	99.08
[illegible]	10	M. E. Atchinson	Services, September 1 to October 31, 1886.	60.00
[illegible]	11	S. E. Atchinson	......do	70.00
[illegible]	12	C. E. Woodin	Services, October 1 to 31, 1886	30.00
[illegible]	13	Lincoln Cook	......do	30.00
[illegible]	14	George Unsell	......do	35.00
[illegible]	15	F. A. Glenn	......do	30.00
[illegible]	16	W. T. Walker	Services, September 1 to October 31, 1886.	80.00
[illegible]	[illegible]	C. T. Reid	......do	100.00
[illegible]	[illegible]	William H. Herron	......do	99.50
[illegible]	[illegible]	W. H. Reynolds	......do	100.00
[illegible]	[illegible]	F. P. Metzger	......do	100.00
[illegible]	[illegible]	Basil Duke	......do	100.00
[illegible]	[illegible]	George L. Hawkins	Services, October 1 to 31, 1886	75.80
[illegible]	[illegible]	E. T. Perkins, jr	......do	75.80
[illegible]	[illegible]	William J. Peters	......do	84.20
[illegible]	[illegible]	H. L. Baldwin, jr	......do	101.10
Nov. [illegible]	[illegible]	P. J. Ryan	Services, October 25 to 31, 1886	5.64
[illegible]	[illegible]	H. L. Baldwin, jr	Field expenses	77.61
[illegible]	[illegible]	F. P. Metzger	Services, November 1 to 9, 1886	14.99
[illegible]	[illegible]	W. W. Nutz	Services, October 1 to November 10, 1886.	33.33
[illegible]	[illegible]	Herbert B. Taylor	Traveling expenses	6.00
[illegible]	[illegible]	......do	Services, October 1 to 15, 1886	25.00
[illegible]	[illegible]	William J. Peters	Field expenses	102.89
[illegible]	[illegible]	George Unsell	Services, November 1 to 13, 1886	15.16
[illegible]	[illegible]	Lincoln Cook	......do	13.00
[illegible]	[illegible]	F. A. Glenn	Services, November 1 to 15, 1886	15.00
[illegible]	[illegible]	C. E. Woodin	Services, November 1 to 18, 1886	18.00
[illegible]	[illegible]	John H. Renshawe	Field expenses	264.77
[illegible]	[illegible]	George Unsell	Traveling expenses	10.40
[illegible]	[illegible]	John H. Renshawe	......do	94.30
[illegible]	[illegible]	George L. Hawkins	Services, November 1 to 30, 1886	73.40
[illegible]	[illegible]	John H. Renshawe	Services, September 1 to 30, 1886	208.30
[illegible]	[illegible]	Basil Duke	Traveling expenses	22.50
[illegible]	[illegible]	William H. Herron	......do	7.25
[illegible]	[illegible]	William J. Peters	Field expenses	23.80
[illegible]	[illegible]	[illegible]	......do	39.75
[illegible]	[illegible]	[illegible]	Services, November 1 to 11, 1886	18.33
[illegible]	[illegible]	[illegible]	Services, September 1 to October 23, 1886.	43.54

Abstract of disbursements made by John H. Renshawe, etc.—Continued.

Date.	No. of voucher.	To whom paid.	For what paid.	Amount.
1886.				
Dec. 15	48	W. H. Reynolds	Traveling expenses	$7.25
15	49	......do	......do	8.85
15	50	H. L. Baldwin, jr	......do	7.70
				2,987.58

Abstract of disbursements made by Arnold Hague, special disbursing agent, U. S. Geological Survey, during the fourth quarter of 1886.

1886.				
Oct. 13	1	T. R. Mallon	Fresh meat	$24.81
13	2	Mammoth Hot Springs Hotel	Field supplies and subsistence	32.24
14	3	Joseph P. Iddings	Traveling expenses	104.80
14	4	Arnold Hague	Miscellaneous expenses	30.68
16	5	J. C. Vilas	Field supplies and subsistence	60.28
21	6	George Bowlin	Traveling expenses	11.00
21	7	Fred Claybrook	......do	11.00
25	8	George C. Howard	Care and forage of public animals	22.50
25	9	E. J. Owenhouse	Storage	15.00
25	10	......do	Field supplies	9.10
25	11	Arnold Hague	Traveling expenses	10.00
25	12	......do	......do	5.25
25	13	......do	Miscellaneous expenses	101.80
31	14	Pay-roll of employés	Salaries, July, 1886	976.14
31	15	......do	Salaries, August, 1886	1,097.08
31	16	......do	Salaries, September, 1886	1,093.20
31	17	......do	Salaries, October, 1886	342.91
Nov. 1	18	Thomas J. Ryder	Traveling expenses	84.05
5	19	W. H. Weed	......do	88.42
Oct. 31	20	Pay-roll of employés	Salaries, October, 1886	628.40
Nov. 17	21	William Hallock	Traveling expenses	62.05
19	22	Arnold Hague	......do	58.15
19	23	Joseph P. Iddings	......do	63.60
29	24	Samuel L. Penfield	......do	75.85
30	25	Pay-roll of employés	Salaries, November, 1886	608.20
Dec. 13	26	A. Lamme & Co	Subsistence stores	156.38
16	27	James A. Clark	Field material and supplies	57.50
24	28	J. C. McCartney	Hauling and storage	25.86
31	29	Pay-roll of employés	Services, December, 1886	623.40
				6,469.65

Abstract of disbursements made by G. K. Gilbert, disbursing agent, U. S. Geological Survey, during the fourth quarter of 1886.

1886.				
Nov. 1	1	G. K. Gilbert	Services, October 1 to 31, 1886	$337.00
1	2	P. A. Johnson & Co	Services, September 2, 1886	5.00
5	3	W. F. McFarland	Services, November 5, 1886	2.00
30	4	G. K. Gilbert	Services, November 1 to 30, 1886	326.00
Dec. 4	5	Dodd's Express Company, New York.	Expressage, December 4, 1886	.50
31	6	G. K. Gilbert	Services, December 1 to 31, 1886	337.00
				1,007.50

Abstract of disbursements made by R. R. Hawkins, special disbursing agent, U. S. Geological Survey, during the fourth quarter of 1886.

1886.				
Oct. 6	1	A. Carlisle & Co	Office and field supplies	$47.18
8	2	William L. Bryan, postmaster	Post-office box-rent	3.00
9	3	A. H. Weber	Traveling expenses	21.25
12	4	John Taylor & Co	Laboratory supplies	33.65
12	5	A. Carlisle & Co	Office, field, and laboratory supplies	20.00
Sept. 12	6	E. A. Halstead	Supplies	20.75
Oct. 18	7	L. Jones	Labor and cartage	7.00

Abstract of disbursements made by R. R. Hawkins, etc.—Continued.

Date.	No. of voucher.	To whom paid.	For what paid.	Amount.
1886.				
Oct. 31	8	Pay-roll	Services, October, 1886	$591.30
Nov. 3	9	Albion S. Howe	Services, October 1 to 31, 1886	60.00
3	10	H. L. House	Laboratory supplies, etc	14.50
6	11	H. W. Turner	Field expenditures	79.61
6	12	......do	Traveling expenses	9.45
6	13	......do	Field expenditures	20.64
8	14	Joseph Bien	Office supplies, etc	5.00
8	15	E. M. Sleator	Maps	3.45
12	16	F. C. Boyce	Services, October 1 to 31, 1886	68.00
12	17	H. Davis	Cartage, etc	10.75
16	18	G. W. Granniss	Rent of rooms	52.66
24	19	George Phillips	Services	24.19
29	20	F. C. Boyce	Services, November 1 to 30, 1886	68.00
30	21	Pay-roll	......do	572.40
30	22	H. A. Messenger	Pasturing public animals	24.00
30	23	Albion S. Howe	Services, November 1 to 30, 18 6	60.00
30	24	G. W. Granniss	Rent of rooms	52.66
Dec. 13	25	Wells, Fargo & Co	Expressage	14.30
14	26	Western Union Telegraph Company.	Transmitting telegrams	5.12
11	27	H. Davis	Cartage, etc	6.00
11	28	H. L. House	Supplies	20.50
24	29	W. Lindgren	Field supplies	89.61
24	30	......do	Traveling expenses	23.40
31	31	Pay-roll	Services, December 1 to 31, 1886	591.30
31	32	Albion S. Howe	......do	60.00
31	33	G. W. Granniss	Rent of rooms	52.66
31	34	A. Doble	Field supplies	10.00
31	35	R. R. Hawkins	Cash expenditures	16.82
				2,759.24

Abstract of disbursements made by A. O'D. Taylor, jr., special disbursing agent, U. S. Geological Survey, during the fourth quarter of 1886.

18 6.				
Sept. 30	1	Pay-roll	Services, September, 1886	$1,108.40
Oct. 11	2	Raphael Pumpelly	Miscellaneous office expenses	60.80
11	3	......do	Traveling expen es	118.48
13	4	Richard Bliss	Bibliographical work	58.25
13	5	Henry J. Green	Instruments, etc	54.00
14	6	Henry Bull, jr	Tel phone rent	11.50
15	7	T. Nelson Dale	Traveling expenses	18.25
22	8	F. E. Swift	Board of party	53.50
23	9	N. Y. and B. D. Express Company	Expressage	11.55
26	10	M. A. Dyke	Provisions	20.10
2[illegible]	11	J. Eliot Wolff	Traveling expenses	10.61
31	12	Pay-roll	Services, October, 1886	883.10
Nov. 1	13	A. Prescott Baker	Rent for October, 1886	50.00
4	14	Sawin's Express	Express charges	2.45
5	15	Edward Stabe	Traveling expenses	7.30
9	16	Charles W. Billings	Oil-stove, etc	8.25
12	17	C. B. Mason	Freight and cart ,ge	7.94
12	18	T. Nelson Dale	Traveling expenses	26.11
17	19	J. H. Flagg	Hire of team, etc	258.50
17	20	Edward Stabe	Pay for November, 1886	8.35
17	21	William H. Hobbs	Traveling expenses	44.26
17	22	Gleason Bros	Provisions	35.42
24	23	William McGrath	Care of horse, etc	31.50
25	24	Roulhac Ruffin	Pay for November, 1886	37.50
25	25	......do	Traveling expenses	16.70
26	26	N. Y. and B. D. Express Company	Express charges	8.05
29	27	T. Nelson Dale	Salary, November, 1886	70.00
29	28	W. H. Hobbs	Pay for November, 1886	23.33
30	29	Pay-roll	Services, November, 1896	523.80
30	30	A. Prescott Baker	Rent for November, 1886	50.00
30	31	Raphael Pumpelly	Traveling expenses	74.60
30	32	......do	Miscellaneous expenses	34.74
Dec. 1	33	Josiah Pierce, jr	Traveling expenses	122.35
1	34	......do	Incidental expenses	19.89
9	35	T. Nelson Dale	Traveling expenses	27.74
31	36	J. H. Flagg	Team hire, etc	32.00
14	37	J. Eliot Wolff	Traveling expenses	7.27
14	38	Josiah Pierce jr	Pay for December, 1886	45.15
71	39	Grace T. Putnam	B. T. Putnam's salary for October, 1886.	58.66

Abstract of disbursements made by A. O'D. Taylor, jr., etc.—Continued.

Date.	No. of voucher.	To whom paid.	For what paid.	Amount.
1886.				
Dec. 17	40	Grace T. Putnam	Field expenses of B. T. Putnam	$15.25
24	41	Raphael Pumpelly	Traveling expenses	21.75
31	42	Richard Bliss	Bibliographical work	42.00
31	43	A. Prescott Baker	Rent for December, 1886	50.00
31	44	Raphael Pumpelly	Pay for December, 1886	337.00
31	45	A. O'D. Taylor, jr	......do	101.10
31	46	T. Nelson Dale	......do	44.85
31	47	Henry Bull, jr	Telephone rent	11.50
				4,608.37

Abstract of disbursements made by Alfred M. Rogers, disbursing agent, U. S. Geological Survey, during the fourth quarter of 1886.

1886.				
Oct. 4	1	R. W. Speer	Correspondence	$2.50
30	2	Denver Fire-clay Company	Laboratory material	84.87
30	3	......do	......do	31.15
30	4	Arthur Kelly	Traveling expenses	47.25
30	5	C. Whitman Cross	......do	90.20
30	6	Colorado Coal and Iron Company	Laboratory material	11.50
30	7	Pay-roll	Services, October, 1886	855.70
30	8	S. F. Emmons	Traveling expenses	45.37
30	9	.....do	.....do	71.25
Nov. 27	10	M. McIntyre	Laboratory material	6.75
Dec. 1	11	Daniels & Fisher	Office furniture	14.25
1	12	Hax, Gurtner & Co	......do	2.50
Nov. 30	13	Pay-roll	Services, November, 1886	838.60
Dec. 31	14	Denver Fire-clay Company	Laboratory material	13.00
28	15	E. Besly & Co	Stationery	1.50
28	16	William L. Patten & Co	Field supplies and expenses	6.53
28	17	W. H. Laurence & Co	Stationery	3.60
28	18	Edwin Green	Office supplies and expenses	3.50
28	19	C. A. Roberts & Co,	Field supplies and expenses	7.50
30	20	Peter McCourt	Rent	200.00
31	21	H. Baumgartin	Services	12.00
31	22	S. F. Emmons	Pay	1,000.00
31	23	Pay-roll	Services, December, 18°6	855.70
31	24	McElroy & Fulivoder	Field supplies and expenses	2.50
31	25	Samuel P. Barbee	Rent	158.35
31	26	S. T. La Duc	Services, October 25 to November 1, 1886.	28.75
31	27	R. J. Spotswood	Services and field supplies	116.00
31	28	John Murphy	Field supplies and expenses	9.50
31	29	H. E. Sylvester & C	Office supplies	15.00
31	30	George H. Eldridge	Traveling expenses	17.55
31	31	Denver Gas Company	Laboratory material	29.60
31	32	Strong & Trombly	Field supplies and expenses	26.10
31	33	J. M. Broadwell	......do	12.00
31	34	Pacific Express Company	Transportation of property	.80
31	35	S. Graham	......do	1.25
31	36	H. Herzberger	Field subsistence	1.80
31	37	Strong & Trombly	Field supplies and expenses	21.05
31	38	C. F. Hicks	......do	15.55
31	39	G. H. Church	......do	23.90
31	40	C. A. Roberts & Co	Field material	1.50
31	41	Chain, Hardy & Co	Stationery	18.75
31	42	W. H. Hyatt	Field supplies and expenses	24.30
31	43	H. Z. Salomon	Field subsistence	35.04
31	44	......do	......do	19.10
31	45	......do	......do	14.40
31	46	.....do	......do	35.85
31	47	.. .. do	......do	33.86
31	48	......do	......do	4.25
31	49	Margaret Hodges	Services, December 31, 1886	1.00
31	50	Daniel Phillips	Services, October, November, and December, 1886.	24.30
31	51	George Linhart	Laboratory material	1.75
31	52	Denver and Rio Grande Railroad Company.	Transportation of property	6.92
31	53	Band M. Railroad Company	......do	21.47
31	54	Wells, Fargo & Co.'s Express	......do	.75
31	55	Pacific Express Company	......do	3.45
31	56	......do	......do	7.30

Abstract of disbursements made by Alfred M. Rogers, etc.—Continued.

Date.	No. of voucher.	To whom paid.	For what paid.	Amount.
1886.				
31	57	Western Union Telegraph Company.	Correspondence	$0.40
31	58	J. H. Smith	Office repairs	.50
31	59	George Fritch	Transportation of property	.65
31	60	Callaway Bros. & Dingwell	Office supplies	.60
				4,990.56

Abstract of disbursements made by John D. McChesney, chief disbursing clerk, U. S. Geological Survey, during the first quarter of 1887.

Date.	No. of voucher.	To whom paid.	For what paid.	Amount.
1887.				
Jan. 10	1	Roland D. Irving	Services, December, 1886	$252.70
10	2	Henry F. Hill	Services, December 1 to 2, 1886	2.58
8	3	A. C. Peale	Traveling expenses	3.30
7	4	B. F. McCaully & Co	Care and forage of public animals	29.50
10	5	G. H. Page	Traveling expenses	17.00
10	6	L. F. Cutter	do	15.05
12	7	N. B. K. Hoffman	do	9.85
12	8	Asher Atkinson	do	20.73
12	9	F. W. Bennett	do	22.93
12	10	W. H. Luster, jr	do	27.66
12	11	P. H. Bevier	do	38.22
12	12	P. D. Staats	do	22.13
12	13	William F. Marvine	do	7.50
12	14	Carl Barus	do	18.70
12	15	F. W. Clarke	do	10.00
12	16	Smedley Bros. & Co	Freight charges	111.48
12	17	J. I. Clawson	Services, November 1 to 21, 1886	28.00
12	18	W. H. Powell	Services, November, 1886	55.00
12	19	E. H. Barbour	Services, October, November, and December, 1886.	350.00
12	20	A. Hermann	do	225.00
12	21	T. A. Bostwick	do	225.00
12	22	M. P. Felch	Services, December, 1886	170.00
12	23	do	Services, July, 1886	170.00
12	24	R. W. Westbrook	Services, October, November, and December, 1886.	150.00
12	25	J. B. Hatcher	Services, December, 1886	150.00
12	26	G. Baur	do	140.00
12	27	Fred. Brown	Services, November and December, 1886.	100.00
12	28	H. Gibb	Services, December, 1886	60.00
12	29	L. B. Bush	do	50.00
13	30	Seth Thomas Clock Company	Supplies for seismometric work	1.50
13	31	Robert Hay	Salary, December, 1886	75.00
13	32	Warren Upham	do	101.10
13	33	Charles W. Howell	Services, November and December, 1886.	120.00
13	34	James R. Thompson	Services during November 1 to December 31, 1886.	23.75
13	35	W. and L. E. Gurley	Instruments	80.52
13	36	Buffalo Dental Manufacturing Company.	Laboratory supplies	45.40
13	37	Lawrence C. Johnson	Traveling expenses	55.85
13	38	Pennsylvania Company	Transportation of assistants	17.50
13	39	M. Lukanitsch	Supplies for repairs of instruments	18.19
13	40	Willard D. Johnson	Traveling expenses	47.31
13	41	do	do	19.00
14	42	Charles S. Thompson	Services, July 15 to August 15, 1886	50.00
14	43	Willard D. Johnson	Miscellaneous field expenses	314.18
14	44	French, Eddy & Co	Freight charges	4.33
14	45	William M. Hughes	Forage and care of public animals	20.00
17	46	Ethan C. Robinson	Field transportation	164.51
14	47	do	do	250.00
14	48	Pennsylvania Railroad Company	Transportation of assistants	7.70
17	49	Chicago, Burlington and Quincy Railroad Company.	do	12.50
14	50	Oregon and California Railroad Company.	do	24.97
14	51	do	do	41.04
14	52	Baltimore and Ohio Railroad Company.	do	38.45
17	53	Baltimore and Potomac Railroad Company.	do	6.00

Abstract of disbursements made by John D. McChesney, etc.—Continued.

Date.	No. of voucher.	To whom paid.	For what paid.	Amount.
1887.				
Jan. 14	54	Charles S. Cudlip	Photographic supplies	$120.41
14	55	Edward Kübel	Cash paid for supplies	11.32
15	56	T. C. Chamberlin	Services, December, 1886	308.30
15	57	Edward J. Hannan	Repairs to laboratory	6.50
17	58	Western Union Telegraph Company.	Telegrams	9.11
17	59	George Ryneal, jr	Office supplies, etc	132.61
18	60	H. R. Geiger	Traveling expenses	38.54
18	61	......do	......do	36.25
18	62	George H. Stone	Services during period September 1 to December 31, 1886.	30.00
18	63	W. F. Cummins	Services during period November 20 to December 31, 1886.	25.00
18	64	Washington Gas-light Company	Gas for December, 1886	121.64
18	65	Atchison, Topeka and Santa Fé Railroad.	Transportation of assistants	38.30
18	66	Chicago and Alton Railroad Company.	......do	7.50
19	67	W. S. Buchanan, proprietor	Freight	3.00
19	68	McCalla & Stavely	Publications	4.00
19	69	Robert Clarke & Co	......do	3.50
19	70	W. H. Walmsley & Co	Glass slips	4.50
19	71	National Press Intelligence Company.	Services	2.45
19	72	Chesapeake and Potomac Telephone Company.	......do	157.20
19	73	Northern Pacific Railroad Company.	Transportation of assistants	50.00
19	74	J. F. Sabin	Publications	4.00
19	75	Northern Pacific Railroad Company.	Transportation of assistants	311.05
19	76	R. C. Jones	Publications	7.00
20	77	E. E. Jackson & Co	Lumber	202.66
20	78	Mutual District Messenger Company.	Rent of night watch, November and December, 1886.	10.00
20	79	Robert Clarke & Co	Publications	32.40
20	80	W. B. Moses & Son	Office furniture	68.00
20	81	John W. Stearns	Services	40.00
20	82	James G. Reaves	Care and feed of public animals	36.00
20	83	H. M. Wilson	Field expenses	7.00
20	84	Lansburg & Bro	Laboratory material	11.84
20	85	F. Alfred Reichardt & Co	Laboratory supplies	44.92
20	86	Washington B. Williams	Office furniture and supplies	40.61
21	87	Western Union Telegraph Company.	Telegrams, December, 1886	5.79
21	88	C. Schneider	Office supplies	6.47
21	89	Great Falls Ice Company	Ice, October, November, and December, 1886.	42.49
21	90	A. F. Dunnington	Cash paid for subsistence	4.50
21	91	J. H. Boring	Services, November 24, 1886, to January 4, 1887.	3.00
21	92	Denver and Rio Grande Western Railroad.	Transportation of assistants	39.30
21	93	Chicago, Milwaukee and St. Paul Railroad.	Freight charges	2.90
21	94	S. L. Brown	Services, January 1 to 15, 1887	15.62
21	95	N. Q. Stewart	......do	2.58
21	96	W. H. Morrison	Publications	17.00
21	97	Publishers of Sabin's Dictionary	......do	4.00
21	98	Gustav E. Stechert	......do	10.62
21	99	Laurence Thompson	Traveling expenses	3.25
21	100	E. W. F. Natter	......do	32.55
22	101	C. A. Schneider's Sons	Carpenter clamps	15.00
21	102	Z. D. Gilman	Laboratory and photographic supplies.	197.82
22	103	William D. Castle	Office furniture and repairs	6.15
22	104	Willard D. Johnson	Miscellaneous field expenses	418.04
22	105	David T. Day	Traveling expenses	7.30
22	106	H. L. Hinkle & Bro	Coal	182.02
24	107	Charles H. Kraft	Laboratory supplies	40.00
24	108	Richard R. Thornton	Washing towels	4.86
25	109	Arthur Watts	Pay, November and December, 1886.	150.00
25	110	Percy L. Green	Traveling expenses	24.50
25	111	......do	Services, November 1 to 10, 1886	22.83
25	112	J. H. Jennings	Traveling expenses	14.83
26	113	W. H. Boyd	Five directories	25.00
27	114	H. L. Smyth	Traveling expenses	21.28
27	115	Lawrence C. Johnson	......do	32.80
27	116	Empire Line	Freight charges	44.20

Abstract of disbursements made by John D. McChesney, etc.—Continued.

Date.	No. of voucher.	To whom paid.	For what paid.	Amount.
1887. Jan. 27	117	Gulf, Colorado and Santa Fé Railroad.	Freight charges	$1.25
27	118	Wm. T. Griffin	Services, January 1 to 2, 1887	3.89
27	119	Baltimore and Ohio Railroad Company.	Freight charges	21.50
27	120	Denver and Rio Grande Railroad Company.	......do	19.81
31	121	Ohio and Mississippi Railroad Company.	Transportation of assistants	20.25
31	122	U. S. Subsistence Department	Subsistence supplies	21.25
31	123	Emil Greiner	Laboratory material	22.20
31	124	Laurence Thompson	Miscellaneous field expenses	8.40
31	125	Willard D. Johnson	......do	313.95
31	126	W. N. Merriam	Services, January, 1887	120.60
31	127	W. S. Bayley	......do	50.00
31	128	J. Henry Blake	......do	155.00
31	129	Sam. H. Scudder	......do	215.30
31	130	J. B. Hatcher	......do	90.00
31	131	G. Baur	......do	140.00
31	132	L. P. Bush	......do	50.00
31	133	O. C. Marsh	......do	344.40
31	134	C. W. Howell	......do	60.00
31	135	J. E. Todd	Services, December, 1886	82.50
31	136	E. H. Sargeant	Services, January, 1887	46.77
31	137	Pay roll of employés	......do	298.10
31	138	......do	......do	529.55
31	139	......do	......do	1,998.00
31	140	......do	......do	1,551.10
31	141	......do	......do	4,758.60
31	142	......do	......do	3,081.57
31	143	......do	......do	2,511.53
31	144	......do	......do	893.90
31	145	......do	......do	867.81
31	146	N. S. Shaler	......do	260.00
31	147	Lawrence C. Johnson	......do	120.60
31	148	M. T. Burns	......do	55.00
31	149	Geo. W. Shutt	......do	258.30
Feb. 1	150	Robert T. Hill	......do	77.50
2	151	Walter Atherton	Services, December 1, 1886, to January 18, 1887.	63.22
2	152	Wm. H. Lovell	Services, January, 1887	77.50
2	153	James T. Jones	......do	46.77
2	154	W. H. Porter	Repairing caligraph, etc	7.50
2	155	Royce & Marean	Electric supplies	3.50
2	156	W. M. Shuster & Sons	Office supplies	75.18
2	157	Warren Upham	Services, January, 18·7	103.30
2	158	Campbell Printing-press Manufacturing Company.	Hawkins counter	12.00
2	159	E. C. Cleaves	Office furniture	7.18
2	160	J. E. Todd	Traveling expenses	62.55
2	161	James G. Bowen	Care and forage of public animals	47.67
4	162	Wm. H. Lovell	Traveling expenses	21.95
4	163	Frank Leverett	......do	127.55
4	164	L. H. Phillips	Pasturage of twenty-two animals	44.00
4	165	Collier Cobb	Pay, January, 1887	50.00
4	166	W. H. Hulery	Subsistence	8.90
5	167	B. F. McCaully & Co	Care and forage of public animals	28.50
7	168	Atlantic and Pacific Railroad	Transportation of assistants	57.40
7	169	Fremont, Elkhorn and Missouri River Railroad.	Freight charges	159.54
7	170	......do	......do	60.02
7	171	Denver and Rio Grande Railroad Company.	......do	25.68
7	172	W. P. Rust	Services, January 1 to 12, 1887	22.50
7	173	Thomas Norwood	Office furniture	4.50
7	174	Goodnow & Wightman	Laboratory supplies	279.29
7	175	H. F. Walling	Services, January, 1887	172.20
7	176	Willard D. Johnson	Cash paid for field expenses	43.31
7	177	Washington Gas-light Company	Gas for January, 1887	124.89
7	178	Eimer & Amend	Laboratory supplies	375.03
7	179	Julius Bien & Co	Copies of sheets of Geological and Topographical Atlas.	470.70
8	180	Chas. S. Cudlip	Photographic supplies	135.24
8	181	Thomas Somerville & Son	Laboratory supplies	25.20
8	182	R. U. Goode	Traveling expenses	25.55
8	183	George W. Knox	Freight charges and hauling	62.38
8	184	William Kerr	Laboratory material	15.66
8	185	Adams Express Company	Freight charges, November, 1886	261.00
8	186	Robert Robertson	Traveling expenses	18.65

Abstract of disbursements made by John D. McChesney, etc.—Continued.

Date.	No. of voucher.	To whom paid.	For what paid.	Amount.
1887.				
Feb. 8	187	Church & Stephenson	Lumber	$9.37
8	188	Appropriation for contingent expenses, Department of the Interior, fiscal year 1886-'87.	Miscellaneous supplies	10.08
9	189	Wilh. P. Stender	Laboratory supplies	105.41
9	190	Trier Brothers	Patent counter	4.86
9	191	William Wesley & Son	Publications	2.83
9	192	Dulan & Co	......do	70.68
9	193	Frank & Weigert	......do	128.42
9	194	Citizens' National Bank	Bill of exchange	4.66
9	195	John F. Paret	File boxes	15.50
9	196	California Southern Railroad	Transportation of assistants	4.85
9	197	Chicago and Northwestern Railway.	......do	11.50
9	198	Texas and Pacific Railway Company.	......do	40.15
9	199	Robert Hay	Traveling expenses	11.30
9	200	Hume, Cleary & Co	Map-mounting material	4.40
9	201	Charles L. Woodward	Publications	5.00
9	202	William J. Park & Co	Artist material	7.62
9	203	L. H. Schneider's Son	Office and laboratory supplies	32.36
10	204	W. T. Walker	Care and forage of public animals	120.00
10	205	......do	......do	90.00
10	206	Baltimore and Ohio Railroad	Freight charges, July, August, and September, 1886.	11.65
10	207	Shepherd & Hurley	Laboratory supplies	3.75
10	208	John C. Brawner	Services during the period from September 17 to November 26, 1886.	206.66
10	209	Charles F. Kendall	Storage, November 9 to December 31, 1886.	13.85
10	210	United Lines Telegraph Company.	Telegrams	.35
12	211	Citizens' National Bank	Bill of exchange	2.09
12	212	F. A. Brockhaus	Publications	180.60
12	213	New Haven Steamboat Company.	Freight charges	40.37
12	214	H. Rosendale	Repairing tools	2.20
12	215	E. S. Greely & Co	Laboratory supplies	54.97
12	216	Robert Leitch & Sons	Supplies for repairs of instruments.	3.53
12	217	C. R. Van Hise	Services during January, 1887	60.00
12	218	W. H. Morrison	Publications	167.35
15	219	James D. and E. S. Dana	......do	12.00
15	220	Gustav E. Stechert	......do	245.75
15	221	Sykes & Gwathney	Tracing map	10.00
15	222	J. Bishop & Co	Repairs to laboratory material	7.95
15	223	T. C. Chamberlin	Traveling expenses	301.64
16	224	Charles J. Bemer	Instruments	405.00
17	225	John W. Stearns	Services, January 1 to 17, 1887	21.93
17	226	Henry S. Williams	Services, October, November, and December, 1886.	375.00
17	227	E. W. F. Natter	Traveling expenses	2.09
17	228	E. E. Pierce	Miscellaneous field expenses	4.80
17	229	Hall & Sons	Laboratory material	43.00
18	230	Wyckoff, Seamans & Benedict	Repairing typewriter	5.40
19	231	Z. D. Gilman	Photographic supplies, etc	137.04
21	232	Northern Pacific Railroad	Freight charges	53.07
21	233	Baltimore & Ohio Railroad	......do	9.69
21	234	Lawrence C. Johnson	Traveling expenses	26.60
21	235	Henry J. Green	Instruments and repairs	176.97
21	236	J. E. Todd	Services during January, 1887	35.00
21	237	Albert Williams, jr	Services, revision of proof	100.00
21	238	H. E. Davidson	Office material	1.80
21	239	John Seipel	Material, repairs to instruments	6.50
21	240	E. W. F. Natter	Miscellaneous field expenses	3.25
21	241	G. E. Manigault	Traveling expenses	39.00
26	242	H. R. Geiger	......do	5.05
28	243	E. P. Keibel	Services during period February 2 to 22, 1887.	45.00
28	244	William H. Dall	Services, February, 1887	155.60
28	245	Robert T. Hill	......do	70.00
28	246	Lawrence C. Johnson	......do	108.80
28	247	Leo Lesquereux	......do	75.00
28	248	......do	Services, January, 1887	75.00
28	249	O. C. Marsh	Services, February, 1887	311.20
28	250	H. Gibb	Services, January 1 to February 28, 1887.	120.00
28	251	G. Baur	Services, February, 1887	140.00
28	252	L. P. Bush	......do	50.00
28	253	Pay-roll of employés	......do	278.80
28	254	......do	......do	4,152.20
28	255	......do	......do	2,802.20
28	256	......do	......do	674.21

Abstract of disbursements made by John D. McChesney, etc.—**Continued.**

Date.	No. of voucher.	To whom paid.	For what paid.	Amount.
1887.				
Feb. 28	257	Pay-roll of employés	Services, February, 1887	$1,879.60
28	258	......do	......do	1,327.80
28	259	......do	......do	807.[illegible]0
28	260	......do	......do	2,520.00
28	261	George W. Shutt	......do	233.40
Mar. 1	262	N. S. Shaler	......do	240.00
1	263	W. S. Bayley	......do	50.00
1	264	C. R. Van Hise	......do	50.00
1	265	W. N. Merriam	......do	108.80
1	266	Pay-roll of employés	......do	505.71
Feb. 26	267	E. H. King	Office furniture	6.00
Mar. 2	268	George Ryneal, jr	Office supplies	11.89
2	269	Washington Gas-light Company	Gas for February, 1887	125.02
2	270	James G. Bowen	Care and forage of public animals	44.50
2	271	John F. Stephenson	Freight charges	3.99
2	272	James D. and E. S. Dana	Publications	6.00
2	273	W. H. Walmsley & Co	Photographic material	37.00
2	274	J. C. Pierce	Storage, December 1, 1886, to February 28, 1887.	9.00
2	275	A. P. Anderson	Pasturage, December 1, 1886, to February 28, 1887.	36.00
2	276	James G. Reaves	Forage and care of public animals	30.00
2	277	E. E. Jackson	Lumber, and milling the same	88.80
2	278	L. H. Phillips	Pasturage, February, 1887	44.00
2	279	Magee Furnace Company	Supplies for repairs to office furniture.	3.75
3	280	William B. Moses & Son	Office furniture and repairs	18.40
3	281	Western Union Telegraph Company.	Telegrams, January, 1887	4.91
3	282	J. Henry Blake	Services, February, 1887	140.00
3	283	Samuel H. Scudder	......do	194.40
3	284	William M. Hughes	Forage and care of public animals	40.00
3	285	N. S. Shaler	Traveling expenses	141.50
3	286	Mutual District Messenger Company.	Messenger service and rental	5.40
3	287	G. H. Williams	Services, October 1, 1886, to February 14, 1887.	100.00
3	288	F. V. Hayden	Salary, December, 1886	337.00
4	289	Joseph F. Page	Field material	4.50
4	290	W. T. Walker	Care and forage of public animals	90.00
4	291	J. B. Hatcher	Pay for February, 1887	90.00
4	292	Robert Robertson	Services, February, 1887	50.00
5	293	Robert Boyd	Laboratory and office supplies	68.60
5	294	N. V. Randolph	Office supplies	102.71
5	295	B. F. McCaully & Co	Care and forage of public animals	96.50
5	296	A. T. Kyler, jr	Pasturage of public animals	159.68
5	297	Charles H. Kraft	Laboratory supplies	24.60
7	298	George H. Stone	Traveling expenses	332.37
7	299	Warren Upham	Pay for February, 1887	98.40
8	300	Lutz Brothers	Office supplies	2.25
8	301	Wash. B. Williams	Office furniture and supplies	31.35
8	302	United States Quartermaster's Department.	Forage	29.14
8	303	W. W. Mildrum	Supplies for repairs of instruments	6.00
8	304	Buffalo Dental Manufacturing Company.	Laboratory material	23.50
8	305	Charles S. Cudlip	Photographic supplies	229.20
8	306	Collier Cobb	Services, February, 1887	50.00
9	307	Charles D. Walcott	Traveling expenses	36.75
9	308	H. L. Pelouze & Son	Office supplies	11.80
9	309	W. and L. E. Gurley	Instruments	90.00
9	310	Baldwin Brothers & Co	Freight	15.25
10	311	Charles W. Howell	Services, February, 1887	60.00
10	312	E. C. Landers	Forage	33.75
10	313	National Press Intelligence Company.	Services, January and February, 1887.	2.50
10	314	James W. Queen & Co	Laboratory material, etc	774.16
12	315	David T. Day	Traveling expenses	2.25
15	316	Chicago, Milwaukee and St. Paul Railroad.	Freight charges	2.94
15	317	Fred. Brown	Pay, January 1 to February 28, 1887	100.00
15	318	Charles S. Platt	Supplies for repairs of instruments	14.25
16	319	Darling, Brown & Sharpe	Repairs to instruments	5.50
18	320	C. N. Witcher	Forage	65.00
18	321	H. L. Hinkle & Bro	Coal	47.90
19	322	Arthur Watts	Services, January and February, 1887	150.00
19	323	John C. Parker	Office supplies	17.30
22	324	Adams Express Company	Freight charges	101.85
22	325	Western Union Telegraph Company.	Telegrams, February, 1887	8.43

Abstract of disbursements made by John D. McChesney, etc.—Continued.

Date.	No. of voucher.	To whom paid.	For what paid.	Amount.
1887.				
Mar. 22	326	J. Karr	Office furniture and supplies	$2.00
22	327	W. B. Moses & Son	Repairs to office furniture	2.50
22	328	W. M. Shuster & Sons	Office and laboratory supplies	14.74
22	329	W. H. Morrison	Publications	10.00
22	330	Lawrence C. Johnson	Traveling expenses	38.28
23	331	John J. Lennon	Services during October, 1886	15.00
23	332	Houghton, Miflin & Co	Publications	6.50
23	333	A. S. Witherbee & Co	do	16.00
24	334	Pennsylvania Railroad Company	Transportation of assistants	56.30
24	335	Chicago, Burlington and Quincy Railroad.	do	12.50
24	336	Baltimore and Ohio Railroad Company.	Freight charges	53.15
24	337	Baltimore and Ohio Telegraph Company.	Telegrams	.80
24	338	Edward Kübel	Cash paid for repairs	9.34
24	339	Charles S. Platt	Supplies for repairs to instruments	3.86
23	340	William H. Dall	Traveling expenses	164.71
25	341	Mutual District Messenger Company.	Rent of night watch	5.00
30	342	J. Bishop & Co	Repairs to laboratory	5.58
31	343	C. F. Schmidt	Storage of public property	15.00
29	344	Roland Hayward	Services, September, 1886	35.00
30	345	Darling, Brown & Sharpe	Re airs to instruments	4.50
29	346	H. S. Hinkle & Bro	Fuel	47.90
31	347	O. C. Marsh	Services, March, 1887	344.40
31	348	J. B. Hatcher	do	150.00
31	349	G. Baur	do	140.00
31	350	M. P. Felch	do	75.00
31	351	H. Gibb	do	60.00
31	352	L. P. Bush	do	50.00
31	353	E. H. Barbour	Services, January 1 to March 31, 1887	350.00
31	354	T. A. Bostwick	do	225.00
31	355	A. Hermann	do	225.00
31	256	R. W. Westbrook	do	165.00
31	357	Pay-roll of employés	Services, March, 1887	298.10
31	358	Lawrence C. Johnson	do	120.60
31	359	Samuel H. Scudder	do	215.30
31	360	J. Henry Blake	do	155.00
31	361	Charles F. Kendall	Storage of public property	24.00
31	362	J. H. Van Auken	One atlas	11.00
31	363	Leo Lesquereux	Services, March, 1887	75.00
31	364	J. Loring Whittington	Office furniture	1.75
31	365	Hume, Cleary & Co	Office supplies	7.10
31	366	George Ryneal, jr	do	6.65
31	367	L. H. Schneider's Son	Supplies, repairs to instruments	34.28
31	368	do	Laboratory supplies	74.80
31	369	Empire Line	Freight charges	57.29
31	370	A. P. Anderson	Services, March, 1887	37.50
31	371	Pay-roll of employés	do	155.00
31	372	Chesapeake and Potomac Telephone Company.	Services, January 1 to March 31, 1887	157.20
31	373	Washington Gas-light Company	Gas, March, 1887	101.76
31	374	W. T. Walker	Care and forage of public animals	90.00
31	375	Z. D. Gilman	Photographic and laboratory supplies.	207.55
31	376	Adams Express Company	Freight charges	57.14
31	377	Royce & Marean	Electric supplies	11.30
31	378	Washington city post-office	Box rent	8.00
31	379	James G. Bowen	Care and forage of public animals	49.25
31	380	R. R. Thornton	Washing towels	5.26
31	381	Warren Upham	Services, March, 1887	103.30
31	382	Charles W. Howell	do	60.00
31	383	James Stevenson	Traveling expenses	31.45
31	384	O. H. P. Clark	Care and forage of public animals	48.77
31	385	Pay-roll of employés	Services, March, 1887	794.50
31	386	do	do	893.90
31	387	do	do	1,451.10
31	388	do	do	4,414.20
31	389	do	do	3,096.40
31	390	do	do	2,748.00
31	391	do	do	2,015.20
31	392	George W. Shutt	do	258.30
31	393	N. S. Shaler	do	270.00
31	394	Robert Robertson	do	50.00
31	395	Collier Cobb	do	50.00
31	396	Thaddeus William Harris	Services, September 1 to 15, 1886	30.00
31	397	B. F. McCaully & Co	Care and forage of public animals	25.50
31	398	L. P. Blair, manager Gas-saving Manufacturing Company.	Gas saver	15.00
				74,671.19

Abstract of disbursements made by P. H. Christie, etc.—Continued.

Date.	No. of voucher.	To whom paid.	For what paid.	Amount.
1886.				
Dec. 9	120	Louis Nell	Miscellaneous field expenses	$102.33
10	121	Fred J. Knight	Traveling expenses	33.60
14	122	E. P. Lane	Miscellaneous field expenses	49.40
16	123	Fred J. Knight	......do	256.59
16	124	Morris Bien	......do	289.52
16	125	L. Morgan	Traveling expenses	23.95
22	126	E. M. Nettleton	Forage of stock	48.33
27	127	Desha Breckenridge	Traveling expenses	42.95
31	128	J. B. Supeler	Forage of stock	42.00
31	129	W. F. Fling	......do	102.98
31	130	E. M. Harnsberger	......do	59.83
31	131	N. B. Dunn	......do	278.10
31	132	E. M. Nettleton	......do	50.00
31	133	Z. N. Lockhart	Hire of transportation	29.75
31	134	Gilbert Thompson	Traveling expenses	60.00
31	135	Pay-roll	Services, December, 1886	3,317.70
31	136	Baker & Hall	Rent of storage	16.67
				17,862.61

Abstract of disbursements made by John H. Renshawe, disbursing agent, U. S. Geological Survey, during the fourth quarter of 1886.

1886.				
Oct. 13	1	Herbert B. Taylor	Services, September 1 to 30, 1886	$50.00
7	2	Fred Hoover	1 horse	100.00
10	3	William J. Peters	Field expenses	54.25
25	4	John H. Renshawe	......do	217.34
25	5	......do	Traveling expenses	11.05
25	6	......do	......do	41.90
28	7	William J. Peters	Field expenses	63.85
28	8	......do	......do	26.50
28	9	H. L. Baldwin, jr	......do	99.08
30	10	M. E. Atchinson	Services, September 1 to October 31, 1886.	60.00
30	11	S. E. Atchinson	......do	70.00
30	12	C. E. Woodin	Services, October 1 to 31, 1886	30.00
30	13	Lincoln Cook	......do	30.00
30	14	George Unsell	......do	35.00
30	15	F. V. Glenn	......do	30.00
30	16	W. T. Walker	Services, September 1 to October 31, 1886.	80.00
30	17	C. T. Reid	......do	100.00
30	18	William H. Herron	......do	99.50
30	19	W. H. Reynolds	......do	100.00
30	20	F. P. Metzger	......do	100.00
30	21	Basil Duke	......do	100.00
30	22	George L. Hawkins	Services, October 1 to 31, 1886	75.80
30	23	E. T. Perkins, jr	......do	75.80
30	24	William J. Peters	......do	84.20
30	25	H. L. Baldwin, jr	......do	101.10
Nov. 1	26	P. J. Ryan	Services, October 25 to 31, 1886	5.64
5	27	H. L. Baldwin, jr	Field expenses	77.61
9	28	F. P. Metzger	Services, November 1 to 9, 1886	14.99
10	29	W. W. Nutz	Services, October 1 to November 10, 1886.	33.33
10	30	Herbert B. Taylor	Traveling expenses	6.00
15	31	......do	Services, October 1 to 15, 1886	25.00
11	32	William J. Peters	Field expenses	102.89
13	33	George Unsell	Services, November 1 to 13, 1886	15.16
13	34	Lincoln Cook	......do	13.00
15	35	F. V. Glenn	Services, November 1 to 15, 1886	15.00
18	36	C. E. Woodin	Services, November 1 to 18, 1886	18.00
27	37	John H. Renshawe	Field expenses	264.77
19	38	George Unsell	Traveling expenses	10.40
Dec. 8	39	John H. Renshawe	......do	94.30
Nov. 30	40	George T. Hawkins	Services, November 1 to 30, 1886	78.40
30	41	John H. Renshawe	Services, September 1 to 30, 1886	208.80
Dec. 7	42	Basil Duke	Traveling expenses	22.50
8	43	William H. Herron	......do	7.25
8	44	William J. Peters	Field expenses	23.80
8	45	......do	......do	39.75
8	46	Basil Duke	Services, November 1 to 11, 1886	18.33
15	47	C. C. Crane	Services, September 1 to October 23, 1886.	43.54

Abstract of disbursements made by John H. Renshawe, etc.—Continued.

Date.	No. of voucher.	To whom paid.	For what paid.	Amount.
1886.				
Dec. 15	48	W. H. Reynolds	Traveling expenses	$7.25
15	49	......do	......do	8.85
15	50	H. L. Baldwin, jr	......do	7.70
				2,987.58

Abstract of disbursements made by Arnold Hague, special disbursing agent, U. S. Geological Survey, during the fourth quarter of 1886.

1886.				
Oct. 13	1	T. R. Mallon	Fresh meat	$34.81
13	2	Mammoth Hot Springs Hotel	Field supplies and subsistence	32.24
14	3	Joseph P. Iddings	Traveling expenses	104.80
14	4	Arnold Hague	Miscellaneous expenses	30.68
16	5	J. C. Vilas	Field supplies and subsistence	60.28
21	6	George Bowlin	Traveling expenses	11.00
21	7	Fred Claybrook	......do	11.00
25	8	George C. Howard	Care and forage of public animals	22.50
25	9	E. J. Owenhouse	Storage	15.00
25	10	......do	Field supplies	9.10
25	11	Arnold Hague	Traveling expenses	10.00
25	12	......do	......do	5.25
25	13	......do	Miscellaneous expenses	101.80
31	14	Pay-roll of employés	Salaries, July, 1886	976.14
31	15	......do	Salaries, August, 1886	1,097.08
31	16	......do	Salaries, September, 1886	1,093.20
31	17	......do	Salaries, October, 1886	342.91
Nov. 1	18	Thomas J. Ryder	Traveling expenses	84.05
5	19	W. H. Weed	......do	88.42
Oct. 31	20	Pay-roll of employés	Salaries, October, 1886	623.40
Nov. 17	21	William Hallock	Traveling expenses	62.05
19	22	Arnold Hague	......do	58.15
19	23	Joseph P. Iddings	......do	63.60
29	24	Samuel L. Penfield	......do	75.85
30	25	Pay-roll of employés	Salaries, November, 1886	608.20
Dec. 13	26	A. Lamme & Co	Subsistence stores	156.38
16	27	James A. Clark	Field material and supplies	57.50
24	28	J. C. McCartney	Hauling and storage	25.86
31	29	Pay-roll of employés	Services, December, 1886	623.40
				6,469.65

Abstract of disbursements made by G. K. Gilbert, disbursing agent, U. S. Geological Survey, during the fourth quarter of 1886.

1886.				
Nov. 1	1	G. K. Gilbert	Services, October 1 to 31, 1886	$337.00
1	2	P. A. Johnson & Co	Services, September 2, 1886	5.00
5	3	W. F. McFarland	Services, November 5, 1886	2.00
30	4	G. K. Gilbert	Services, November 1 to 30, 1886	326.00
Dec. 4	5	Dodd's Express Company, New York.	Expressage, December 4, 1886	.50
31	6	G. K. Gilbert	Services, December 1 to 31, 1886	337.00
				1,007.50

Abstract of disbursements made by R. R. Hawkins, special disbursing agent, U. S. Geological Survey, during the fourth quarter of 1886.

1886.				
Oct. 6	1	A. Carlisle & Co	Office and field supplies	$47.18
8	2	William L. Bryan, postmaster	Post-office box-rent	3.00
9	3	A. H. Weber	Traveling expenses	21.25
12	4	John Taylor & Co	Laboratory supplies	33.65
12	5	A. Carlisle & Co	Office, field, and laboratory supplies	20.00
Sept. 12	6	E. A. Halstead	Supplies	20.75
Oct. 18	7	L. Jones	Labor and cartage	7.09

Abstract of disbursements made by R. R. Hawkins, etc.—Continued.

Date.	No. of voucher.	To whom paid.	For what paid.	Amount.
1886.				
Oct. 31	8	Pay-roll	Services, October, 1886	$591.30
Nov. 3	9	Albion S. Howe	Services, October 1 to 31, 1886	60.00
3	10	H. L. House	Laboratory supplies, etc	14.50
6	11	H. W. Turner	Field expenditures	79.61
6	12	......do	Traveling expenses	9.45
6	13	......do	Field expenditures	20.64
8	14	Joseph Bien	Office supplies, etc	5.00
8	15	E. M. Sleator	Maps	3.45
12	16	F. C. Boyce	Services, October 1 to 31, 1886	68.00
12	17	H. Davis	Cartage, etc	10.75
16	18	G. W. Granniss	Rent of rooms	52.66
24	19	George Phillips	Services	24.19
29	20	F. C. Boyce	Services, November 1 to 30, 1886	68.00
30	21	Pay-roll	......do	572.40
30	22	H. A. Messenger	Pasturing public animals	24.00
30	23	Albion S. Howe	Services, November 1 to 30, 18 6	60.00
30	24	G. W. Granniss	Rent of rooms	52.66
Dec. 13	25	Wells, Fargo & Co	Expressage	14.30
14	26	Western Union Telegraph Company.	Transmitting telegrams	5.12
11	27	H. Davis	Cartage, etc	6.00
11	28	H. L. House	Supplies	20.50
24	29	W. Lindgren	Field supplies	89.61
24	30	......do	Traveling expenses	23.40
31	31	Pay-roll	Services, December 1 to 31, 1886	591.30
31	32	Albion S. Howe	......do	60.00
31	33	G. W. Granniss	Rent of rooms	52.66
31	34	A. Doble	Field supplies	10.00
31	35	R. R. Hawkins	Cash expenditures	16.82
				2,759.24

Abstract of disbursements made by A. O'D. Taylor, jr., special disbursing agent, U. S. Geological Survey, during the fourth quarter of 1886.

Date.	No. of voucher.	To whom paid.	For what paid.	Amount.
18 6.				
Sept. 30	1	Pay-roll	Services, September, 1886	$1,108.40
Oct. 11	2	Raphael Pumpelly	Miscellaneous office expenses	60.80
11	3	......do	Traveling expen es	118.48
13	4	Richard Bliss	Bibliographical work	58.25
13	5	Henry J. Green	Instruments, etc	54.00
14	6	Henry Bull, jr	Tel phone rent	11.50
15	7	T. Nelson Dale	Traveling expenses	18.25
22	8	F. E. Swift	Board of party	53.50
23	9	N. Y. and B. D. Express Company	Expressage	11.55
26	10	M. A. Dyke	Provisions	20.10
2[illegible]	11	J. Eliot Wolff	Traveling expenses	10.61
31	12	Pay-roll	Services, October, 1886	833.10
Nov. 1	13	A. Prescott Baker	Rent for October, 1886	50.00
4	14	Sawin's Express	Express charges	2.45
5	15	Edward Stabe	Traveling expenses	7.30
9	16	Charles W. Billings	Oil-stove, etc	8.25
12	17	C. B. Mason	Freight and cart .ge	7.94
12	18	T. Nelson Dale	Traveling expenses	26.11
17	19	J. H. Flagg	Hire of team, etc	253.50
17	20	Edward Stabe	Pay for November, 1886	8.35
17	21	William H. Hobbs	Traveling expenses	44.26
17	22	Gleason Bros	Provisions	35.42
24	23	William McGrath	Care of horse, etc	31.50
25	24	Roulhac Ruffin	Pay for November, 1886	37.50
25	25	......do	Traveling expenses	16.70
26	26	N. Y. and B. D. Express Company	Express charges	8.05
29	27	T. Nelson Dale	Salary, November, 1886	70.00
29	28	W. H. Hobbs	Pay for November, 1886	28.33
30	29	Pay-roll	Services, November, 1886	523.80
30	30	A. Prescott Baker	Rent for November, 1886	50.00
30	31	Raphael Pumpelly	Traveling expenses	74.60
30	32	......do	Miscellaneous expenses	34.74
Dec. 1	33	Josiah Pierce, jr	Traveling expenses	122.35
1	34	......do	Incidental expenses	19.89
9	35	T. Nelson Dale	Traveling expenses	27.74
31	36	J. H. Flagg	Team hire, etc	32.00
14	37	J. Eliot Wolff	Traveling expenses	7.27
14	38	Josiah Pierce jr	Pay for December, 1886	45.15
71	39	Grace T. Putnam	B. T. Putnam's salary for October, 1886.	58.68

Abstract of disbursements made by A. O'D. Taylor, jr., etc.—Continued.

Date.	No. of voucher.	To whom paid.	For what paid.	Amount.
1886.				
Dec. 17	40	Grace T. Putnam	Field expenses of B. T. Putnam	$15.25
24	41	Raphael Pumpelly	Traveling expenses	21.75
31	42	Richard Bliss	Bibliographical work	42.00
31	43	A. Prescott Baker	Rent for December, 1886	50.00
31	44	Raphael Pumpelly	Pay for December, 1886	387.00
31	45	A. O'D. Taylor, jr	......do	101.10
31	46	T. Nelson Dale	......do	44.85
31	47	Henry Bull, jr	Telephone rent	11.50
				4,608.37

Abstract of disbursements made by Alfred M. Rogers, disbursing agent, U. S. Geological Survey, during the fourth quarter of 1886.

1886.				
Oct. 4	1	R. W. Speer	Correspondence	$2.50
30	2	Denver Fire-clay Company	Laboratory material	84.87
30	3	......do	......do	31.15
30	4	Arthur Kelly	Traveling expenses	47.25
30	5	C. Whitman Cross	......do	90.20
30	6	Colorado Coal and Iron Company	Laboratory material	11.50
30	7	Pay-roll	Services, October, 1886	855.70
30	8	S. F. Emmons	Traveling expenses	45.37
30	9	.....do	......do	71.25
Nov. 27	10	M. McIntyre	Laboratory material	6.75
Dec. 1	11	Daniels & Fisher	Office furniture	14.25
1	12	Hax, Gurtner & Co	......do	2.50
Nov. 30	13	Pay-roll	Services, November, 1886	888.60
Dec. 31	14	Denver Fire-clay Company	Laboratory material	13.00
28	15	E. Besly & Co	Stationery	1.50
28	16	William L. Patten & Co	Field supplies and expenses	6.58
28	17	W. H. Laurence & Co	Stationery	3.60
28	18	Edwin Green	Office supplies and expenses	3.50
28	19	C. A. Roberts & Co,	Field supplies and expenses	7.50
30	20	Peter McCourt	Rent	200.00
31	21	H. Baumgartin	Services	12.00
31	22	S. F. Emmons	Pay	1,000.00
31	23	Pay-roll	Services, December, 18°6	855.70
31	24	McElroy & Fulivoder	Field supplies and expenses	2.50
31	25	Samuel P. Barbee	Rent	158.35
31	26	S. T. La Duc	Services, October 25 to November 1, 1886.	28.75
31	27	R. J. Spotswood	Services and field supplies	116.00
31	28	John Murphy	Field supplies and expenses	9.50
31	29	H. E. Sylvester & C	Office supplies	15.00
31	30	George H. Eldridge	Traveling expenses	17.55
31	31	Denver Gas Company	Laboratory material	29.60
31	32	Strong & Trombly	Field supplies and expenses	26.10
31	33	J. M. Broadwell	......do	12.00
31	34	Pacific Express Company	Transportation of property	.80
31	35	S. Graham	......do	1.25
31	36	H. Herzberger	Field subsistence	1.80
31	37	Strong & Trombly	Field supplies and expenses	21.05
31	38	C. F. Hicks	......do	15.55
31	39	G. H. Church	......do	23.90
31	40	C. A. Roberts & Co	Field material	1.50
31	41	Chain, Hardy & Co	Stationery	18.75
31	42	W. H. Hyatt	Field supplies and expenses	24.30
31	43	H. Z. Salomon	Field subsistence	35.04
31	44	......do	......do	19.10
31	45	......do	......do	14.40
31	46	......do	......do	35.85
31	47	......do	......do	33.86
31	48	......do	......do	4.25
31	49	Margaret Hodges	Services, December 31, 1886	1.00
31	50	Daniel Phillips	Services, October, November, and December, 1886.	24.30
31	51	George Linhart	Laboratory material	1.75
31	52	Denver and Rio Grande Railroad Company.	Transportation of property	6.92
31	53	Band M. Railroad Company	......do	21.47
31	54	Wells, Fargo & Co.'s Express	......do	.75
31	55	Pacific Express Company	......do	3.45
31	56	......do	......do	7.30

Abstract of disbursements made by Alfred M. Rogers, etc.—Continued.

Date.	No. of voucher.	To whom paid.	For what paid.	Amount.
1886.				
31	57	Western Union Telegraph Company.	Correspondence	$0.40
31	58	J. H. Smith	Office repairs	.50
31	59	George Fritch	Transportation of property.	.65
31	60	Callaway Bros. & Dingwell	Office supplies	.60
				4,990.56

Abstract of disbursements made by John D. McChesney, chief disbursing clerk, U. S. Geological Survey, during the first quarter of 1887.

1887.				
Jan. 10	1	Roland D. Irving	Services, December, 1886	$252.70
10	2	Henry F. Hill	Services, December 1 to 2, 1886	2.58
8	3	A. C. Peale	Traveling expenses	3.30
7	4	B. F. McCaully & Co	Care and forage of public animals	29.50
10	5	G. H. Page	Traveling expenses	17.00
10	6	L. F. Cutter	do	15.05
12	7	N. B. K. Hoffman	do	9.85
12	8	Asher Atkinson	do	20.73
12	9	F. W. Bennett	do	22.93
12	10	W. H. Luster, jr	do	27.66
12	11	P. H. Bevier	do	38.22
12	12	P. D. Staats	do	22.13
12	13	William F. Marvine	do	7.50
12	14	Carl Barus	do	18.70
12	15	F. W. Clarke	do	10.00
12	16	Smedley Bros. & Co	Freight charges	111.48
12	17	J. I. Clawson	Services, November 1 to 21, 1886	28.00
12	18	W. H. Powell	Services, November, 1886	55.00
12	19	E. H. Barbour	Services, October, November, and December, 1886.	350.00
12	20	A. Hermann	do	225.00
12	21	T. A. Bostwick	do	225.00
12	22	M. P. Felch	Services, December, 1886	170.00
12	23	do	Services, July, 1886	170.00
12	24	R. W. Westbrook	Services, October, November, and December, 1886.	150.00
12	25	J. B. Hatcher	Services, December, 1886	150.00
12	26	G. Baur	do	140.00
12	27	Fred. Brown	Services, November and December, 1886.	100.00
12	28	H. Gibb	Services, December, 1886	60.00
12	29	L. B. Bush	do	50.00
13	30	Seth Thomas Clock Company	Supplies for seismometric work	1.50
13	31	Robert Hay	Salary, December, 1886	75.00
13	32	Warren Upham	do	101.10
13	33	Charles W. Howell	Services, November and December, 1886.	120.00
13	34	James R. Thompson	Services during November 1 to December 31, 1886.	28.75
13	35	W. and L. E. Gurley	Instruments	80.52
13	36	Buffalo Dental Manufacturing Company.	Laboratory supplies	45.40
13	37	Lawrence C. Johnson	Traveling expenses	55.85
13	38	Pennsylvania Company	Transportation of assistants	17.50
13	39	M. Lukanitsch	Supplies for repairs of instruments	18.19
13	40	Willard D. Johnson	Traveling expenses	47.31
13	41	do	do	19.00
14	42	Charles S. Thompson	Services, July 15 to August 15, 1886	50.00
14	43	Willard D. Johnson	Miscellaneous field expenses	314.18
14	44	French, Eddy & Co	Freight charges	4.33
14	45	William M. Hughes	Forage and care of public animals	20.00
17	46	Ethan C. Robinson	Field transportation	164.51
14	47	do	do	250.00
14	48	Pennsylvania Railroad Company	Transportation of assistants	7.70
17	49	Chicago, Burlington and Quincy Railroad Company.	do	12.50
14	50	Oregon and California Railroad Company.	do	24.97
14	51	do	do	41.04
14	52	Baltimore and Ohio Railroad Company.	do	38.45
17	53	Baltimore and Potomac Railroad Company.	do	6.00

Abstract of disbursements made by John D. McChesney, etc.—Continued.

Date.	No. of voucher.	To whom paid.	For what paid.	Amount.
1887.				
Jan. 14	54	Charles S. Cudlip	Photographic supplies	$120.41
14	55	Edward Kübel	Cash paid for supplies	11.32
15	56	T. C. Chamberlin	Services, December, 1886	303.30
15	57	Edward J. Hannan	Repairs to laboratory	6.50
17	58	Western Union Telegraph Company.	Telegrams	9.11
17	59	George Ryneal, jr	Office supplies, etc	182.61
18	60	H. R. Geiger	Traveling expenses	38.54
18	61	......do	......do	36.25
18	62	George H. Stone	Services during period September 1 to December 31, 1886.	30.00
18	63	W. F. Cummins	Services during period November 20 to December 31, 1886.	25.00
18	64	Washington Gas-light Company	Gas for December, 1886	121.64
18	65	Atchison, Topeka and Santa Fé Railroad.	Transportation of assistants	38.30
18	66	Chicago and Alton Railroad Company.	......do	7.50
19	67	W. S. Buchanan, proprietor	Freight	3.00
19	68	McCalla & Stavely	Publications	4.00
19	69	Robert Clarke & Co	......do	3.50
19	70	W. H. Walmsley & Co	Glass slips	4.50
19	71	National Press Intelligence Company.	Services	2.45
19	72	Chesapeake and Potomac Telephone Company.	......do	157.20
19	73	Northern Pacific Railroad Company.	Transportation of assistants	50.00
19	74	J. F. Sabin	Publications	4.00
19	75	Northern Pacific Railroad Company.	Transportation of assistants	311.05
19	76	R. C. Jones	Publications	7.00
20	77	E. E. Jackson & Co	Lumber	202.66
20	78	Mutual District Messenger Company.	Rent of night watch, November and December, 1886.	10.00
20	79	Robert Clarke & Co	Publications	32.40
20	80	W. B. Moses & Son	Office furniture	68.00
20	81	John W. Stearns	Services	40.00
20	82	James G. Reaves	Care and feed of public animals	36.00
20	83	H. M. Wilson	Field expenses	7.00
20	84	Lansburg & Bro	Laboratory material	11.84
20	85	F. Alfred Reichardt & Co	Laboratory supplies	44.92
20	86	Washington B. Williams	Office furniture and supplies	40.61
21	87	Western Union Telegraph Company.	Telegrams, December, 1886	5.79
21	88	C. Schneider	Office supplies	6.47
21	89	Great Falls Ice Company	Ice, October, November, and December, 1886.	42.49
21	90	A. F. Dunnington	Cash paid for subsistence	4.50
21	91	J. H. Boring	Services, November 24, 1886, to January 4, 1887.	3.00
21	92	Denver and Rio Grande Western Railroad.	Transportation of assistants	39.30
21	93	Chicago, Milwaukee and St. Paul Railroad.	Freight charges	2.90
21	94	S. L. Brown	Services, January 1 to 15, 1887	15.62
21	95	N. Q. Stewart	......do	2.58
21	96	W. H. Morrison	Publications	17.00
21	97	Publishers of Sabin's Dictionary	......do	4.00
21	98	Gustav E. Stechert	......do	10.62
21	99	Laurence Thompson	Traveling expenses	3.25
21	100	E. W. F. Natter	......do	32.55
22	101	C. A. Schneider's Sons	Carpenter clamps	15.00
21	102	Z. D. Gilman	Laboratory and photographic supplies.	197.82
22	103	William D. Castle	Office furniture and repairs	6.15
22	104	Willard D. Johnson	Miscellaneous field expenses	418.04
22	105	David T. Day	Traveling expenses	7.30
22	106	H. L. Hinkle & Bro	Coal	182.02
24	107	Charles H. Kraft	Laboratory supplies	40.00
24	108	Richard R. Thornton	Washing towels	4.86
25	109	Arthur Watts	Pay, November and December, 1886.	150.00
25	110	Percy L. Green	Traveling expenses	24.50
25	111	......do	Services, November 1 to 10, 1886	22.83
25	112	J. H. Jennings	Traveling expenses	14.83
26	113	W. H. Boyd	Five directories	25.00
27	114	H. L. Smyth	Traveling expenses	21.28
27	115	Lawrence C. Johnson	......do	32.80
27	116	Empire Line	Freight charges	44.20

Abstract of disbursements made by John D. McChesney, etc.—Continued.

Date.	No. of voucher.	To whom paid.	For what paid.	Amount.
1887. Jan. 27	117	Gulf, Colorado and Santa Fé Railroad.	Freight charges	$1.25
27	118	Wm. T. Griffin	Services, January 1 to 2, 1887	3.89
27	119	Baltimore and Ohio Railroad Company.	Freight charges	21.50
27	120	Denver and Rio Grande Railroad Company.	......do	19.81
31	121	Ohio and Mississippi Railroad Company.	Transportation of assistants	20.25
31	122	U. S. Subsistence Department	Subsistence supplies	21.25
31	123	Emil Greiner	Laboratory material	22.20
31	124	Laurence Thompson	Miscellaneous field expenses	8.40
31	125	Willard D. Johnson	......do	318.95
31	126	W. N. Merriam	Services, January, 1887	120.60
31	127	W. S. Bayley	......do	50.00
31	128	J. Henry Blake	......do	155.00
31	129	Sam. H. Scudder	......do	215.30
31	130	J. B. Hatcher	......do	90.00
31	131	G. Baur	......do	140.00
31	132	L. P. Bush	......do	50.00
31	133	O. C. Marsh	......do	344.40
31	134	C. W. Howell	......do	60.00
31	135	J. E. Todd	Services, December, 1886	32.50
31	136	E. H. Sargeant	Services, January, 1887	46.77
31	137	Pay roll of employés	......do	298.10
31	138	......do	......do	529.55
31	139	......do	......do	1,998.00
31	140	......do	......do	1,551.10
31	141	......do	......do	4,758.60
31	142	......do	......do	3,031.57
31	143	......do	......do	2,511.53
31	144	......do	......do	893.90
31	145	......do	......do	867.81
31	146	N. S. Shaler	......do	260.00
31	147	Lawrence C. Johnson	......do	120.60
31	148	M. T. Burns	......do	55.00
31	149	Geo. W. Shutt	......do	258.30
Feb. 1	150	Robert T. Hill	......do	77.50
2	151	Walter Atherton	Services, December 1, 1886, to January 18, 1887.	63.22
2	152	Wm. H. Lovell	Services, January, 1887	77.50
2	153	James T. Jones	......do	46.77
2	154	W. H. Porter	Repairing caligraph, etc	7.50
2	155	Royce & Marean	Electric supplies	3.50
2	156	W. M. Shuster & Sons	Office supplies	75.18
2	157	Warren Upham	Services, January, 18-7	103.30
2	158	Campbell Printing-press Manufacturing Company.	Hawkins counter	12.00
2	159	E. C. Cleaves	Office furniture	7.13
2	160	J. E. Todd	Traveling expenses	62.55
2	161	James G. Bowen	Care and forage of public animals	47.67
4	162	Wm. H. Lovell	Traveling expenses	21.96
4	163	Frank Leverett	......do	127.55
4	164	L. H. Phillips	Pasturage of twenty-two animals	44.00
4	165	Collier Cobb	Pay, January, 1887	50.00
4	166	W. H. Hulery	Subsistence	8.90
5	167	B. F. McCaully & Co	Care and forage of public animals	28.50
7	168	Atlantic and Pacific Railroad	Transportation of assistants	57.40
7	169	Fremont, Elkhorn and Missouri River Railroad.	Freight charges	159.54
7	170	......do	......do	60.02
7	171	Denver and Rio Grande Railroad Company.	......do	25.68
7	172	W. P. Rust	Services, January 1 to 12, 1887	22.50
7	173	Thomas Norwood	Office furniture	4.50
7	174	Goodnow & Wightman	Laboratory supplies	279.29
7	175	H. F. Walling	Services, January, 1887	172.20
7	176	Willard D. Johnson	Cash paid for field expenses	43.31
7	177	Washington Gas-light Company	Gas for January, 1887	124.89
7	178	Eimer & Amend	Laboratory supplies	375.08
7	179	Julius Bien & Co	Copies of sheets of Geological and Topographical Atlas.	470.70
8	180	Chas. S. Cudlip	Photographic supplies	135.24
8	181	Thomas Somerville & Son	Laboratory supplies	25.20
8	182	R. U. Goode	Traveling expenses	25.55
8	183	George W. Knox	Freight charges and hauling	62.38
8	184	William Kerr	Laboratory material	15.66
8	185	Adams Express Company	Freight charges, November, 1886	261.00
8	186	Robert Robertson	Traveling expenses	18.65

Abstract of disbursements made by John D. McChesney, etc.—Continued.

Date.	No. of voucher.	To whom paid.	For what paid.	Amount.
1887.				
Feb. 8	187	Church & Stephenson	Lumber	$9.37
8	188	Appropriation for contingent expenses, Department of the Interior, fiscal year 1886-'87.	Miscellaneous supplies	10.08
9	189	Wilh. P. Stender	Laboratory supplies	105.41
9	190	Trier Brothers	Patent counter	4.86
9	191	William Wesley & Son	Publications	2.88
9	192	Dulan & Co	do	70.68
9	193	Frank & Weigert	do	198.42
9	194	Citizens' National Bank	Bill of exchange	4.66
9	195	John F. Paret	File boxes	15.50
9	196	California Southern Railroad	Transportation of assistants	4.85
9	197	Chicago and Northwestern Railway.	do	11.50
9	198	Texas and Pacific Railway Company.	do	40.15
9	199	Robert Hay	Traveling expenses	11.80
9	200	Hume, Cleary & Co	Map-mounting material	4.40
9	201	Charles L. Woodward	Publications	5.00
9	202	William J. Park & Co	Artist material	7.62
9	203	L. H. Schneider's Son	Office and laboratory supplies	82.36
10	204	W. T. Walker	Care and forage of public animals	129.00
10	205	do	do	90.00
10	206	Baltimore and Ohio Railroad	Freight charges, July, August, and September, 1886.	11.65
10	207	Shepherd & Hurley	Laboratory supplies	3.75
10	208	John C. Brawner	Services during the period from September 17 to November 26, 1886.	200.66
10	209	Charles F. Kendall	Storage, November 9 to December 31, 1886.	13.85
10	210	United Lines Telegraph Company.	Telegrams	.35
12	211	Citizens' National Bank	Bill of exchange	2.09
12	212	F. A. Brockhaus	Publications	180.60
12	213	New Haven Steamboat Company.	Freight charges	40.37
12	214	H. Rosendale	Repairing tools	2.20
12	215	E. S. Greely & Co	Laboratory supplies	54.97
12	216	Robert Leitch & Sons	Supplies for repairs of instruments.	3.53
12	217	C. R. Van Hise	Services during January, 1887	60.00
12	218	W. H. Morrison	Publications	167.35
15	219	James D. and E. S. Dana	do	12.00
15	220	Gustav E. Stechert	do	245.75
15	221	Sykes & Gwathney	Tracing map	10.00
15	222	J. Bishop & Co	Repairs to laboratory material	7.95
15	223	T. C. Chamberlin	Traveling expenses	301.64
16	224	Charles J. Bemer	Instruments	405.00
17	225	John W. Stearns	Services, January 1 to 17, 1887	21.93
17	226	Henry S. Williams	Services, October, November, and December, 1886.	375.00
17	227	E. W. F. Natter	Traveling expenses	2.09
17	228	E. E. Pierce	Miscellaneous field expenses	4.80
17	229	Hall & Sons	Laboratory material	43.00
18	230	Wyckoff, Seamans & Benedict	Repairing typewriter	5.40
19	231	Z. D. Gilman	Photographic supplies, etc	137.04
21	232	Northern Pacific Railroad	Freight charges	53.07
21	233	Baltimore & Ohio Railroad	do	9.69
21	234	Lawrence C. Johnson	Traveling expenses	26.60
21	235	Henry J. Green	Instruments and repairs	176.97
21	236	J. E. Todd	Services during January, 1887	35.00
21	237	Albert Williams, jr	Services, revision of proof	100.00
21	238	H. E. Davidson	Office material	1.80
21	239	John Seipel	Material, repairs to instruments	6.50
21	240	E. W. F. Natter	Miscellaneous field expenses	3.25
21	241	G. E. Manigault	Traveling expenses	39.00
26	242	H. R. Geiger	do	5.05
28	243	E. P. Keibel	Services during period February 2 to 22, 1887.	45.00
28	244	William H. Dall	Services, February, 1887	155.60
28	245	Robert T. Hill	do	70.00
28	246	Lawrence C. Johnson	do	108.80
28	247	Leo Lesquereux	do	75.00
28	248	do	Services, January, 1887	75.00
28	249	O. C. Marsh	Services, February, 1887	311.20
28	250	H. Gibb	Services, January 1 to February 28, 1887.	120.00
28	251	G. Baur	Services, February, 1887	140.00
28	252	L. P. Bush	do	50.00
28	253	Pay-roll of employés	do	278.80
28	254	do	do	4,152.20
28	255	do	do	2,802.20
28	256	do	do	674.21

Abstract of disbursements made by John D. McChesney, etc.—Continued.

Date.	No. of voucher.	To whom paid.	For what paid.	Amount.
1887.				
Feb. 28	257	Pay-roll of employés	Services, February, 1887	$1,879.60
28	258	......do	......do	1,327.80
28	259	......do	......do	807.20
28	260	......do	......do	2,520.00
28	261	George W. Shutt	......do	283.40
Mar. 1	262	N. S. Shaler	......do	240.00
1	263	W. S. Bayley	......do	50.00
1	264	C. R. Van Hise	......do	50.00
1	265	W. N. Merriam	......do	108.80
1	266	Pay-roll of employés	......do	505.71
Feb. 26	267	E. H. King	Office furniture	6.00
Mar. 2	268	George Ryneal, jr	Office supplies	11.89
2	269	Washington Gas-light Company	Gas for February, 1887	125.02
2	270	James G. Bowen	Care and forage of public animals	44.50
2	271	John F. Stephenson	Freight charges	3.99
2	272	James D. and E. S. Dana	Publications	6.00
2	273	W. H. Walmsley & Co	Photographic material	37.00
2	274	J. C. Pierce	Storage, December 1, 1886, to February 28, 1887.	9.00
2	275	A. P. Anderson	Pasturage, December 1, 1886, to February 28, 1887.	36.00
2	276	James G. Reaves	Forage and care of public animals	30.00
2	277	E. E. Jackson	Lumber, and milling the same	88.80
2	278	L. H. Phillips	Pasturage, February, 1887	44.00
2	279	Magee Furnace Company	Supplies for repairs to office furniture.	3.75
3	280	William B. Moses & Son	Office furniture and repairs	18.40
3	281	Western Union Telegraph Company.	Telegrams, January, 1887	4.91
3	282	J. Henry Blake	Services, February, 1887	140.00
3	283	Samuel H. Scudder	......do	194.40
3	284	William M. Hughes	Forage and care of public animals	40.00
3	285	N. S. Shaler	Traveling expenses	141.50
3	286	Mutual District Messenger Company.	Messenger service and rental	5.40
3	287	G. H. Williams	Services, October 1, 1886, to February 14, 1887.	100.00
3	288	F. V. Hayden	Salary, December, 1886	337.00
4	289	Joseph F. Page	Field material	4.50
4	290	W. T. Walker	Care and forage of public animals	90.00
4	291	J. B. Hatcher	Pay for February, 1887	90.00
4	292	Robert Robertson	Services, February, 1887	50.00
5	293	Robert Boyd	Laboratory and office supplies	63.60
5	294	N. V. Randolph	Office supplies	102.71
5	295	B. F. McCaully & Co	Care and forage of public animals	26.50
5	296	A. T. Kyler, jr	Pasturage of public animals	159.68
5	297	Charles H. Kraft	Laboratory supplies	24.60
7	298	George H. Stone	Traveling expenses	332.37
7	290	Warren Upham	Pay for February, 1887	93.40
8	300	Lutz Brothers	Office supplies	2.25
8	301	Wash. B. Williams	Office furniture and supplies	31.35
8	302	United States Quartermaster's Department.	Forage	29.14
8	303	W. W. Mildrum	Supplies for repairs of instruments.	6.00
8	304	Buffalo Dental Manufacturing Company.	Laboratory material	23.50
8	305	Charles S. Cudlip	Photographic supplies	229.20
8	306	Collier Cobb	Services, February, 1887	50.00
9	307	Charles D. Walcott	Traveling expenses	36.75
9	308	H. L. Pelouze & Son	Office supplies	11.80
9	309	W. and L. E. Gurley	Instruments	90.00
9	310	Baldwin Brothers & Co	Freight	15.25
10	311	Charles W. Howell	Services, February, 1887	60.00
10	312	E. C. Landers	Forage	33.75
10	313	National Press Intelligence Company.	Services, January and February, 1887.	2.50
10	314	James W. Queen & Co	Laboratory material, etc	774.16
12	315	David T. Day	Traveling expenses	2.25
15	316	Chicago, Milwaukee and St. Paul Railroad.	Freight charges	2.24
15	317	Fred. Brown	Pay, January 1 to February 28, 1887	100.00
15	318	Charles S. Platt	Supplies for repairs of instruments.	14.25
16	319	Darling, Brown & Sharpe	Repairs to instruments	5.50
18	320	C. N. Witcher	Forage	65.00
18	321	H. L. Hinkle & Bro	Coal	47.90
19	322	Arthur Watts	Services, January and February, 1887	150.00
19	323	John C. Parker	Office supplies	17.30
22	324	Adams Express Company	Freight charges	101.85
22	325	Western Union Telegraph Company.	Telegrams, February, 1887	8.43

Abstract of disbursements made by John D. McChesney, etc.—Continued.

Date.	No. of voucher.	To whom paid.	For what paid.	Amount.
1887.				
Mar. 22	326	J. Karr	Office furniture and supplies	$2.00
22	327	W. B. Moses & Son	Repairs to office furniture	2.50
22	328	W. M. Shuster & Sons	Office and laboratory supplies	14.74
22	329	W. H. Morrison	Publications	10.00
22	330	Lawrence C. Johnson	Traveling expenses	38.28
23	331	John J. Lennon	Services during October, 1886	15.00
23	332	Houghton, Miflin & Co	Publications	6.50
23	333	A. S. Witherbee & Co	do	16.00
24	334	Pennsylvania Railroad Company	Transportation of assistants	56.30
24	335	Chicago, Burlington and Quincy Railroad.	do	12.50
24	336	Baltimore and Ohio Railroad Company.	Freight charges	53.15
24	337	Baltimore and Ohio Telegraph Company.	Telegrams	.80
24	338	Edward Kübel	Cash paid for repairs	9.34
24	339	Charles S. Platt	Supplies for repairs to instruments	3.86
23	340	William H. Dall	Traveling expenses	164.71
25	341	Mutual District Messenger Company.	Rent of night watch	5.00
30	342	J. Bishop & Co	Repairs to laboratory	5.58
31	343	C. F. Schmidt	Storage of public property	15.00
29	344	Roland Hayward	Services, September, 1886	85.00
30	345	Darling, Brown & Sharpe	Re airs to instruments	4.50
29	346	H. S. Hinkle & Bro	Fuel	47.90
31	347	O. C. Marsh	Services, March, 1887	344.40
31	348	J. B. Hatcher	do	150.00
31	349	G. Baur	do	140.00
31	350	M. P. Felch	do	75.00
31	351	H. Gibb	do	60.00
31	352	L. P. Bush	do	50.00
31	353	E. H. Barbour	Services, January 1 to March 31, 1887	350.00
31	354	T. A. Bostwick	do	225.00
31	355	A. Hermann	do	225.00
31	256	R. W. Westbrook	do	165.00
31	357	Pay-roll of employés	Services, March, 1887	298.10
31	358	Lawrence C. Johnson	do	120.60
31	359	Samuel H. Scudder	do	215.30
31	360	J. Henry Blake	do	155.00
31	361	Charles F. Kendall	Storage of public property	24.00
31	362	J. H. Van Auken	One atlas	11.00
31	363	Leo Lesquereux	Services, March, 1887	75.00
31	364	J. Loring Whittington	Office furniture	1.75
31	365	Hume, Cleary & Co	Office supplies	7.10
31	366	George Ryneal, jr	do	6.65
31	367	L. H. Schneider's Son	Supplies, repairs to instruments	84.28
31	368	do	Laboratory supplies	74.80
31	369	Empire Line	Freight charges	57.29
31	370	A. P. Anderson	Services, March, 1887	87.50
31	371	Pay-roll of employés	do	155.00
31	372	Chesapeake and Potomac Telephone Company.	Services, January 1 to March 31, 1887	157.20
31	373	Washington Gas-light Company	Gas, March, 1887	101.76
31	374	W. T. Walker	Care and forage of public animals	90.00
31	375	Z. D. Gilman	Photographic and laboratory supplies.	207.55
31	376	Adams Express Company	Freight charges	57.14
31	377	Royce & Marean	Electric supplies	11.30
31	378	Washington city post-office	Box rent	8.00
31	379	James G. Bowen	Care and forage of public animals	49.25
31	380	R. R. Thornton	Washing towels	5.26
31	381	Warren Upham	Services, March, 1887	108.30
31	382	Charles W. Howell	do	60.00
31	383	James Stevenson	Traveling expenses	31.45
31	384	O. H. P. Clark	Care and forage of public animals	48.77
31	385	Pay-roll of employés	Services, March, 1887	794.50
31	386	do	do	893.90
31	387	do	do	1,451.10
31	388	do	do	4,414.20
31	389	do	do	3,096.40
31	390	do	do	2,748.00
31	391	do	do	2,015.20
31	392	George W. Shutt	do	258.30
31	393	N. S. Shaler	do	270.00
31	394	Robert Robertson	do	50.00
31	395	Collier Cobb	do	50.00
31	396	Thaddeus William Harris	Services, September 1 to 15, 1886	30.00
31	397	B. F. McCaully & Co	Care and forage of public animals	25.50
31	398	L. P. Blair, manager Gas-saving Manufacturing Company.	Gas saver	16.00
				74,671.19

Abstract of disbursements made by John D. McChesney, etc.—Continued.

SALARIES, OFFICE GEOLOGICAL SURVEY.

Date.	No. of voucher.	To whom paid.	For what paid.	Amount.
1887.				
Jan. 18	1	Thomas J. Ryder	Services, January 1 to 15, 1887	$41.67
31	2	Pay-roll of employés	Services, January, 1887	2,978.67
Feb. 28	3	......do	Services, February, 1887	2,694.30
Mar. 31	4	......do	Services, March, 1887	2,982.80
				8,697.44

Abstract of disbursements made by P. H. Christie, special disbursing agent, U. S. Geological Survey, during the first quarter of 1887.

Date.	No. of voucher.	To whom paid.	For what paid.	Amount.
1887.				
Jan. 15	A	P. H. Christie	Miscellaneous field expenses (New England).	$1,404.13
15	B	......do	......do	2,312.52
15	C	......do	......do	777.67
31	1	Pay-roll	Services, January, 1887	3,387.88
31	2	E. M. Harnsberger	Forage of stock	40.00
31	3	E. M. Nettleton	......do	50.00
31	4	J. B. Supler	......do	21.00
31	5	W. F. Fling	......do	52.00
31	6	N. B. Dunn	......do	189.00
31	7	Baker & Hall	Rent, storage	10.00
Feb. 28	8	Pay-roll	Services, February, 1887	2,912.60
28	9	N. B. Dunn	Forage of stock	184.50
28	10	E. M. Harnsberger	......do	40.00
28	11	E. M. Nettleton	......do	50.00
28	12	J. B. Supler	......do	21.00
28	13	W. F. Fling	......do	52.00
28	14	Baker & Hall	Rent, storage	10.00
Mar. 15	15	C. W. Watkins	Services	11.00
15	16	C. G. Van Hook	Traveling expenses	4.45
15	17	W. T. Griswold	Miscellaneous field expenses	8.50
15	18	D. B. Darby	Veterinary services	5.00
31	19	Pay-roll	Services, March, 1887	3,117.57
31	20	N. B. Dunn	Forage of stock	184.50
31	21	W. F. Fling	......do	52.00
31	22	E. M. Harnsberger	......do	40.00
31	23	E. M. Nettleton	......do	50.00
31	24	J. B. Supler	......do	21.00
31	25	Baker & Hall	Storage	10.00
				15,018.32

Abstract of disbursements made by John H. Renshawe, disbursing agent, U. S. Geological Survey, during the first quarter of 1887.

Date.	No. of voucher.	To whom paid.	For what paid.	Amount.
1887.				
Jan. 24	1	S. E. Atchison	Services, November 1 to 26, 1886	$24.49
24	2	W. T. Walker	Services, November 1 to 17, 1886	22.66
24	3	C. F. Schmidt	Storage	9.33
24	4	M. E. Atchison	Services, November 1 to 7, 1886	7.00
24	5	......do	Traveling expenses	13.95
24	6	John H. Renshawe	Field expenses	58.80
				136.23

Abstract of disbursements made by Arnold Hague, special disbursing agent, U. S. Geological Survey, during the first quarter of 1887.

Date.	No. of voucher.	To whom paid.	For what paid.	Amount.
1887.				
Jan. 31	1	Pay-roll of employés	Services, January, 1887	$637.20
Feb. 28	2	......do	Services, February, 1887	575.60
Mar. 9	3	E. J. Owenhouse	Storage of public property	15.00
16	4	Charles H. Stuart	Pasturage of public animals	100.16
23	5	Charles I. Cohen	Paste-board trays	9.59
31	6	Pay-roll of employés	Services, March, 1887	712.20
				2,049.75

Abstract of disbursements made by G. K. Gilbert, disbursing agent, U. S. Geological Survey, during the first quarter of 1887.

Date.	No. of voucher.	To whom paid.	For what paid.	Amount.
1887.				
Jan. 31	1	G. K. Gilbert	Services, January 1 to 31, 1887	$344.40
Feb. 28	2	......do	Services, February 1 to 28, 1887	311.20
Mar. 31	3	......do	Services, March 1 to 31, 1887	344.40
23	4	H. Drew & Bro	Map	17.50
31	5	G. K. Gilbert	Traveling expenses	234.80
				1,252.30

Abstract of disbursements made by R. R. Hawkins, special disbursing agent, U. S. Geological Survey, during the first quarter of 1887.

Date.	No. of voucher.	To whom paid.	For what paid.	Amount.
1887.				
Jan. 3	1	John Taylor & Co	Laboratory supplies	$51.80
3	2	B. Westermann & Co	Journals	10.00
3	3	Frank Barnard & Co	Fuel	4.70
3	4	L. Jones	Cartage	2.00
7	5	A. Carlisle & Co	Supplies	19.83
8	6	Postmaster	Post-office box	3.00
12	7	H. Davis	Cartage and labor	16.25
14	8	Samuel C. Partridge	Photographic material	2.15
14	9	W. H. Smyth	Sun prints	1.20
14	10	H. L. Howse	Oil	7.00
21	11	H. W. Turner	Field expenditures	18.64
21	12	..... do	Traveling expenses	50.25
21	13	H. A. Messenger	Pasturage	12.00
21	14	A. Lietz & Co	Repairs	10.00
21	15	H. Davis	Supplies and labor	7.70
26	16	George W. Smethurst	Pasturage	27.50
31	17	Pay-roll	Services, January, 1887	604.60
Feb. 3	18	Albion S. Howe	Services, January 1 to 31, 1887	60.00
3	19	Goldberg, Bowen & Co	Field supplies	7.31
3	20	Samuel C. Partridge	Photographic supplies	6.20
3	21	Wells, Fargo & Co	Expressage	3.50
3	22	A. Carlisle & Co	Stationery, etc	7.99
4	23	W. H. Melville	Traveling expenses	68.25
14	24	H. W. Turner	.....do	24.70
14	25	G. W. Grannis	Rent of rooms	52.66
14	26	H. W. Turner	Field expenditures	19.87
14	27	Goldberg, Bowen & Co	Field supplies	30.00
28	28	Pay-roll	Services, February, 1887	545.80
28	29	Albion S. Howe	Services, February 1 to 28, 1887	60.00
28	30	H. A. Messenger	Pasturage	22.50
23	31	G. W. Grannis	Rent of rooms	52.66
Mar. 3	32	H. Davis	Cartage, etc	6.40
3	33	W. B. Walkup & Co	Mounting maps	6.55
3	34	W. T. Thomson	Repairs	5.00
21	35	H. W. Turner	Field expenditures	15.87
25	36	......do	Traveling expenses	23.60
31	37	H. A. Messenger	Foraging public animals	15.00
31	38	Albion S. Howe	Services, March 1 to 31, 1887	60.00
31	39	Pay-roll	......do	604.60
31	40	G. W. Grannis	Rent of rooms	52.66
31	41	R. R. Hawkins	Cash expenditures	6.00
				2,605.94

Abstract of disbursements made by A. O'D. Taylor, jr., special disbursing agent, U. S. Geological Survey, during the first quarter of 1887.

Date.	No. of voucher.	To whom paid.	For what paid.	Amount.
1887.				
Jan. 7	1	A. B. Corbin	Stationery	$5.37
8	2	William H. Hobbs	Traveling expenses	4.00
8	3	......do	Incidental expenses	1.05
8	4	Ada F. Crandall	Temporary services	11.75
20	5	Raphael Pumpelly	Miscellaneous expenses	25.93
31	6	Pay-roll	Services, January, 1887	672.70
Feb. 1	7	A. Prescott Baker	Rent for January, 1887	50.00
1	8	J. Eliot Wolff	Pay to January 31, 1887	144.57
1	9	M. Cottrell	One table	5.00
2	10	Langley & Sharpe	Four clothes-horses	5.40
3	11	J. Eliot Wolff	Traveling expenses	12.27

Abstract of disbursements made by A. O'D. Taylor, jr., etc.—Continued.

Date.	No. of voucher.	To whom paid.	For what paid.	Amount.
1887.				
Feb. 24	12	Sawin's Express	Freight and cartage	$12.55
24	13	Newport Water Works	Six months' water rate	9.00
28	14	Raphael Pumpelly	Pay for February, 1887	311.20
28	15	A. O'D. Taylor, jr	......do	93.40
28	16	T. Nelson Dale	......do	125.00
28	17	Josiah Pierce, jr	......do	100.00
28	18	A. Prescott Baker	Rent for February, 1887	50.00
Mar. 1	19	Richard Bliss	Bibliographical work	43.80
2	20	Raphael Pumpelly	Miscellaneous expenses	49.25
11	21	Keuffel & Esser	Drawing material	10.67
19	22	G. P. Putnam's Sons	Stationery supplies	6.30
22	23	Swinburne, Peckham & Co	Packing boxes, etc	3.73
24	24	E. and H. T. Anthony & Co	Photographic supplies	7.27
30	25	Frank H. Wilks	Two parallel rulers	16.00
31	26	Pay-roll	Services, March, 1887	672.70
31	27	A. Prescott Baker	Rent for March, 1887	50.00
31	28	J. Eliot Wolff	Pay to March 31, 1887	100.00
				2,598.91

Abstract of disbursements made by Alfred M. Rogers, disbursing agent, U. S. Geological Survey, during the first quarter of 1887.

Date.	No. of voucher.	To whom paid.	For what paid.	Amount.
1887.				
Jan. 31	1	Pay-roll	Services, January, 1887	$867.50
Feb. 4	2	A. B. Ingolls	Office repair	2.00
8	3	Denver Water Company	Laboratory material	37.50
10	4	Scott & Murch	Office furniture	7.50
26	5	Denver Lithographic Company	Books and maps	13.00
Mar. 2	6	Kursthus & Peters	Field supplies	4.55
2	7	H. Z. Salomon	Field subsistence	36.69
2	8	......do	......do	22.56
2	9	Denver Fire-clay Company	Laboratory material	5.75
2	10	E. Besley & Co	Stationery	1.45
2	11	W. L. Patten & Co	Field supplies	1.37
4	12	Skinner Bros. & Wright	Field material	3.50
4	13	William Dingle	Office supplies	2.00
28	14	Pay-roll	Services, February, 1887	705.00
22	15	George H. Eldridge	Traveling expenses	32.30
22	16	V. R. Radcliff	Field supplies and expenses	26.75
22	17	L. B. Ames	......do	1.75
22	18	Thomas Fahey	......do	27.62
31	19	S. F. Emmons	Pay, January 1 to March 31, 1887	1,000.00
31	20	Pay-roll	Services, March, 1887	702.50
31	21	Peter McCourt	Rent	150.00
31	22	Sam. P. Barbee	......do	158.40
31	23	H. Baumgartner	Services, January 1 to March 31, 1887	12.00
31	24	Denver Gas Company	Laboratory material	20.80
31	25	Margaret Hodges	Services, January 1 to March 31, 1887	1.75
Feb. 26	26	Burlington and Missouri River Railroad.	Transportation of property	15.88
Mar. 25	27	Pacific Express Company	......do	15.55
25	28	Western Union Telegraph Company.	Correspondence	.30
31	29	George H. Eldridge	Traveling expenses	67.99
31	30	R. J. Spotswood	Services, ranching stock	64.50
31	31	H. E. Sylvester & Co	Office supplies	7.50
31	32	C. A. Kendrick	Services, ranching stock	79.80
31	33	J. H. Smith & Co	Office repair	.85
31	34	R. W. Speer, postmaster	Correspondence	2.50
31	35	W. G. Brown	Laboratory material	11.50
31	36	Edward Laharty	Services, January, February, and March, 1887.	13.75
				4,124.26

Abstract of disbursements made by John D. McChesney, chief disbursing agent, U. S. Geological Survey, during the second quarter of 1887.

Date.	No. of voucher.	To whom paid.	For what paid.	Amount.
1887.				
Apr. 5	1	Roland D. Irving	Services, January 1 to March 31, 1887	$750.00
6	2	M. J. Copeland & Co	Office supplies	10.00
11	3	Charles S. Cudlip	Photographic supplies	134.01
13	4	James Forrister	Services, March 21 to 26, 1887	12.00
13	5	Amos Scott	Services, January 1 to March 31, 1887	180.00
13	6	Fred Brown	Services, March, 1887	50.00
13	7	C. R. Van Hise	......do	80.00
13	8	W. M. Shuster & Sons	Office supplies	4.86
13	9	W. J. McGee	Traveling expenses	40.15
13	10	Burlington and Missouri River Railroad in Nebraska.	Transportation of assistants	18.50
13	11	Baltimore and Ohio Railroad Company.	......do	33.00
14	12	H. L. Hinkle & Bro	Fuel	47.90
14	13	Great Falls Ice Company	Ice, January, February, March, 1887	39.90
14	14	W. H. Porter	Repairs to office furniture	5.50
14	15	Z. D. Gilman	Photographic material and supplies	86.10
14	16	John B. Rogers	Traveling expenses	6.10
14	17	Charles J. Field	Office supplies	3.50
14	18	Union Stone Company	Laboratory supplies	3.75
15	19	David T. Day	Traveling expenses	52.85
15	20	G. H. Page	Services, April 1 to 15, 1887	25.00
15	21	M. Fox & Co	Diamond dust	5.00
15	22	Goodman & Wightman	Laboratory material	3.95
15	23	Vance & Walbridge	Transportation of supplies	18.20
15	24	A. Lietz & Co	Repairs to instruments	68.50
15	25	H. W. Johns Manufacturing Company.	Laboratory supplies	.85
15	26	J. E. Todd	Services, February and March, 1887	45.00
18	27	William M. Hughes	Care and forage of public animals	20.00
18	28	Quartermaster's Department, U. S. Army.	Forage	20.70
18	29	James Conwell	Forage, etc	12.40
18	30	Subsistence Department, U. S. Army.	Subsistence supplies	16.45
18	31	W. H. Hulvey	......do	7.00
18	32	E. E. Howell	Geological specimens	15.00
18	33	Ralph Stockman Tarr	Services, February and March, 1887	80.00
18	34	Quartermaster's Department, U. S. Army.	Tents	39.28
18	35	W. S. Bayley	Services, March, 1887	50.00
19	36	Pennsylvania Railroad Company	Transportation of assistants	21.70
19	37	New York and New England Railroad.	......do	11.45
20	38	Mutual District Messenger Company.	Rent of night watch	5.00
20	39	Baltimore and Ohio Telegraph Company.	Telegrams, March, 1887	.70
20	40	E. E. Jackson & Co	Lumber	104.82
20	41	J. H. Mills & Co	Office supplies	6.85
20	42	Julius Bien & Co	Copies of United States maps and geological and topographical atlas.	313.45
20	43	John R. Proctor	Services during the period from November, 1886, to March, 1887.	350.00
20	44	William Kerr	Laboratory material	4.50
20	45	Emil Greiner	Repairs to laboratory material	3.50
20	46	National Press Intelligence Company.	Services, March, 1887	2.40
20	47	Western Union Telegraph Company.	Telegrams, March, 1887	7.41
20	48	J. S. Topham	Photographic material	13.00
20	49	Shepherd & Hurley	Laboratory material	12.00
20	50	R. D. Salisbury	Traveling expenses	39.50
20	51	.....do	Services, January 1 to April 9, 1887	175.00
20	52	Z. D. Gilman	Photographic and laboratory supplies.	151.20
21	53	George C. Cook	Photographs of earthquake	7.05
21	54	Eleanor T. Wragg	Drawings	30.00
21	55	S. Lewis Simons	Preparing map of earthquake region.	25.00
22	56	H. L. Hinkle & Bro	Fuel	47.90
22	57	Carl Kramer	Laboratory material	21.89
22	58	M. Ganlon	Publications	6.92
22	59	F. A. Brockhaus	......do	34.15
22	60	Citizens' National Bank	Bills of exchange	1.91
22	61	J. Bishop & Co	Repairs to laboratory material	13.27
22	62	Robert Boyd	Office supplies	59.67

Abstract of disbursements made by John D. McChesney, etc.—Continued.

Date.	No. of voucher.	To whom paid.	For what paid.	Amount.
1887.				
Apr. 26	63	Thomas Parry	Traveling expenses	26.35
26	64	W. B. Lane	do	29.80
26	65	C. W. Hayes	do	31.35
26	66	Lawrence C. Johnson	do	58.10
36	67	George Ryneal, jr	Photographic and office supplies	10.80
28	68	John F. Paret	Stationery	36.38
30	69	L. H. Phillips	Pasturage, March and April, 1887	88.00
30	70	Lawrence C. Johnson	Services, April, 1877	115.40
30	71	Charles W. Howell	do	60.00
30	72	Arthur Watts	Services, March, 1887	75.00
30	73	J. B. Hatcher	Services, April, 1887	160.00
30	74	F. Berger	Services, January 1 to April 30, 1887	280.00
30	75	G. Baur	Services, April, 1887	140.00
30	76	L. P. Bush	do	50.00
30	77	O. C. Marsh	do	329.70
30	78	Pay-roll of employés	do	213.30
30	79	do	do	330.60
30	80	do	do	2,597.40
30	81	do	do	2,972.60
30	82	do	do	4,171.15
30	83	do	do	1,272.10
30	84	do	do	1,932.80
30	85	do	do	855.55
30	86	do	do	658.50
30	87	George M. Geddes	Services, April 1 to 15, 1887	25.00
30	88	W. J. Grambs	Services, April, 1887	74.20
30	89	Philip R. Fowle	do	59.30
30	90	George W. Shutt	do	247.25
May 2	91	Pay-roll of employés	do	558.30
2	92	H. R. Geiger	Traveling expenses	30.25
2	93	W. S. Bayley	Services, April, 1887	50.00
3	94	M. C. Lee	Forage and care of public animals	19.00
3	95	E. E. Jackson	Lumber	7.79
3	96	J. and H. Berge	Laboratory material	41.11
3	97	W. T. Walker	Care and forage of public animals	90.00
3	98	A. P. Anderson	Services, April, 1887	37.50
3	99	J. Henry Blake	do	148.30
3	100	Sam. H. Scudder	do	206.00
3	101	Roland D. Irving	do	247.25
3	102	Leo Lesquereux	do	75.00
3	103	C. F. Kendall	do	2.00
3	104	James G. Bowen	Care and forage of public animals	68.00
3	105	Charles H. Kraft	Laboratory supplies	23.80
3	106	J. Bishop & Co	Repairs to laboratory material	5.28
3	107	Warren Upham	Services, April, 1887	98.90
4	108	H. L. Hinkle & Bro	Fuel	47.90
4	109	Roland D. Irving	Traveling expenses	108.07
5	110	Robert Robertson	Services, April, 1887	50.00
5	111	Collier Cobb	do	50.00
4	112	N. S. Shaler	do	260.00
5	113	Washington Gas-light Company	Gas for April	108.88
5	114	S. L. Brown	Making 21 thin sections	4.62
6	115	I. C. Russell	Cash paid for miscellaneous expenses	130.20
6	116	Wyckoff, Seamans & Benedict	Rental of type writer	5.00
6	117	B. F. McCaully & Co	Care and forage of public animals	25.50
6	118	Joseph F. Page	Supplies for repairs to field material	1.25
7	119	Quartermaster's Department, U. S. Army.	Field material	19.64
7	120	Lawrence C. Johnson	Traveling expenses	59.20
7	121	William C. Day	Services, January 1 to February 15, 1887.	100.00
7	122	Jinzoo Adachi	Services, April 8 to May 2, 1887	10.00
7	123	M. P. Felch	Services, April, 1887	170.00
9	124	W. N. Merriam	Services, March and April, 1887	236.00
9	125	J. W. Powell	Traveling expenses	21.30
10	126	John Mason	Publications	4.00
10	127	C. B. Atchinson	Repairing photographic tank.	16.00
11	128	W. H. Walmsley & Co	Laboratory and photographic material.	23.30
11	129	Arthur Watts	Services, April, 1887	75.00
13	130	C. E. Dutton	Traveling expenses	72.50
13	131	A. T. Kyler, jr	Pasturage of public animals	126.75
13	132	Richmond and Danville Railroad	Transportation of assistants	35.00
14	133	Emil Starek	Services, May 1 and 2, 1887	6.59
16	134	A. G. Tinker	Services, April, 1887	40.00
16	135	Joseph Brown	do	85.00
16	136	Marcus Benjamin	do	50.00
16	137	Eimer & Amend	Laboratory material and supplies	60.22
16	138	Baltimore and Potomac Railroad.	Transportation of assistants	18.00

Abstract of disbursements made by John D. McChesney, etc.—Continued.

Date.	No. of voucher.	To whom paid.	For what paid.	Amount.
1887.				
May 16	139	Mutual District Messenger Company.	Rent of night watch	$5.00
16	140	Easton & Rupp	Office supplies	1.25
16	141	L. C. Schmidt	Services, May 1 to 14, 1887	24.00
18	142	Western Union Telegraph Company.	Telegrams	3.55
18	143	A. Kramm	Repairs to instruments	10.25
18	144	Gayton A. Douglas & Co	Photographic supplies	12.40
18	145	Pennsylvania Railroad Company.	Transportation of assistants	24.45
19	146	Z. D. Gilman	Photographic supplies	178.68
20	147	David T. Day	Traveling expenses	8.55
20	148	Henry J. Biddle	Services	100.00
20	149	Israel C. Russell	Traveling expenses	37.15
20	150	J. F. Wright	Services, May 16, 1887	1.50
23	151	Edward Kübel	Cash paid for repairs to instruments	8.70
23	152	G. E. Marrigault	Services, February 10 to April 13, 1887	100.00
23	153	R. C. Jones	Publications	6.00
24	154	J. and H. Berge	Laboratory supplies	33.00
24	155	James G. Reaves	Pasturage of public animals	33.39
25	156	L. H. Schneider's Son	Laboratory and office supplies	107.82
26	157	W. H. Porter	Rental of caligraph	14.43
31	158	L. Moxley	Laboratory supplies	10.80
31	159	Emil Jonscher	Instrument cases and repairs	58.50
31	160	J. Henry Blake	Salary, May, 1887	153.40
31	161	Samuel H. Scudder	do	213.00
31	162	Lawrence C. Johnson	do	119.20
31	163	Leo Lesquereux	do	75.00
31	164	O. C. Marsh	do	340.60
31	165	G. Baur	do	140.00
31	166	H. Gibb	Salary, April and May, 1887	120.00
31	167	L. P. Bush	Salary, May, 1887	50.00
31	168	Pay-roll of employés	do	283.40
31	169	N. S. Shaler	do	260.00
28	170	Fred W. Pilling	Office and photographic supplies	13.68
31	171	George W. Shutt	Services, May, 1887	255.50
31	172	Pay-roll of employés	do	883.90
31	173	do	do	2,951.56
31	174	do	do	4,179.90
31	175	do	do	1,287.40
31	176	do	do	2,928.10
31	177	do	do	599.00
31	178	Charles A. Ashburner	Services, collecting statistics, 887	650.00
31	179	S. D. Howie	Services, May, 1887	88.70
31	180	W. J. Shaw	do	37.10
31	181	Charles Oley	do	66.77
31	182	Pay-roll of employés	do	153.40
31	183	H. R. Geiger	do	127.80
31	184	R. B. Cameron	do	50.00
31	185	F. Berger	do	70.00
June 1	186	John F. Stephenson	Freight charges and hauling	3.69
1	187	Charles S. Cudlip	Photographic supplies	139.86
1	188	J. S. Topham	Instrument case	7.50
1	189	Roland D. Irving	Services, May, 1887	255.50
2	190	George Cartner	Publications	7.00
2	191	C. R. Van Hise	Services between April 1 and May 3, 1887.	90.00
2	192	J. B. Hatcher	Services, May, 1887	160.00
2	193	L. L. Dewees	Field supplies	4.50
3	194	A. H. Thompson	Services, May, 1887	230.00
3	195	B. F. McCaully & Co	Care and forage of public animals, May, 1887.	68.00
3	196	James G. Bowen	do	65.50
3	197	Washington Gas-light Company	Gas for May, 1887	102.14
3	198	William Wurdemann	Repairs to instruments	38.90
3	199	S. J. Kubel	Engraving	8.13
3	200	J. B. Smith	Repairs of field material	3.00
3	201	do	Subsistence supplies	34.31
3	202	do	do	16.83
3	203	do	Field material and supplies	16.31
3	204	W. T. Walker	Care and forage of public animals, May, 1887.	90.00
3	205	William Greenow	Laboratory material	71.00
3	206	New York Central and Hudson River Railroad.	Transportation of freight	1.00
4	207	A. F. Dunnington	Salary, May, 1887	119.20
6	208	O. H. P. Clark	Care, forage and pasturage of animals.	13.00
7	209	Julius Bien & Co	250 copies of 9-sheets topographical and geological atlas.	162.05
7	210	J. E. Todd	Services, April 1 to May 3, 1887	36.00

Abstract of disbursements made by John D. McChesney, etc.—Continued.

Date.	No. of voucher.	To whom paid.	For what paid.	Amount.
1887.				
June 7	211	Robert Robertson	Services, May, 1887	$50.00
7	212	Collier Cobb	do	50.00
7	213	John R. Proctor	Services, April 1 to May 31, 1887	150.00
7	214	B. Westermann & Co	Publications	.60
7	215	Lawrence C. Johnson	Traveling expenses	34.35
7	216	N. D. C. Hodges	Publications	.40
7	217	M. P. Felch	Services, May, 1887	170.00
7	218	Fred Brown	Services, April and May, 1887	800.00
9	219	Lester F. Ward	Traveling expenses	71.45
9	220	Robert Leitch & Sons	Castings for instruments	10.70
9	221	Benjamin Whips	Services, June 6 and 7, 1887	4.00
9	222	Virginia and Truckee Railroad	Freight charges	.63
9	223	Leonard Schultz & Son	Supplies for repairs to instruments	5.25
9	224	James W. Queen & Co	Laboratory and instruments supplies.	245.82
9	225	Charles H. Kraft	Laboratory supplies	28.70
9	226	Easton & Rupp	Office supplies	4.60
9	227	George Ryneal, jr	Office and artists' supplies	11.95
9	228	E. Morrison	Office supplies	6.25
9	229	John C. Parker	do	2.25
9	230	Adams Express Company	Freight charges	88.10
9	231	M. W. Beveridge	Office supplies and furniture	8.96
10	232	George W. Knox	Freight charges, January to March, 1887.	65.82
10	233	Mutual District Messenger Company.	Rent of night watch	5.00
10	234	W. B. Moses & Son	Office supplies	4.75
10	235	Wash. B. Williams	do	8.25
13	236	George H. Boone	Services, June 10 and 11, 1887	4.00
11	237	H. L. Hinkle & Bros	Coal	47.90
13	238	H. R. Geiger	Traveling expenses	94.92
13	239	I. C. Russell	Cash paid for field expenses	71.25
13	240	R. B. Long	Field material	2.25
14	241	Warren Upham	Services, May, 1887	102.20
14	242	Edward Kahler	Instruments	42.00
14	243	E. Everett Hayden	Services, June 1 to 14, 1887	46.15
15	244	W. S. Bayley	Services, May, 1887	60.00
16	245	D. W. Cronin	Services, June 1 to 16, 1887	28.00
17	246	Western Union Telegraph Company.	Telegrams, May, 1887	18.57
17	247	Ollie McClain	Services	8.45
17	248	Joseph Brown	Services, May, 1887	85.00
17	249	A. G. Tinker	do	40.00
17	250	J. E. Todd	Expenses, January 1 to May 13, 1887	17.60
17	251	E. F. Brooks	Office supplies	.85
18	252	A. G. Gedney	Repairs to stamp	1.00
20	253	Pennsylvania Railroad Company	Transportation of assistants	22.40
20	254	James M. Swank	Services, January 1 to April 30, 1887	800.00
22	255	W. J. McGee	Traveling expenses	55.77
22	256	J. S. Diller	do	108.05
23	257	W. H. Warner	Material for repairs to instruments	16.92
28	258	Nelson H. Darton	Traveling expenses	72.70
28	259	F. F. Chisholm	Services	200.00
28	260	C. Kirchhoff, jr	do	200.00
27	261	Z. D. Gilman	Photographic and laboratory supplies.	811.56
2[illegible]	262	Baltimore and Ohio Railroad Company.	Transportation of assistants	14.20
30	263	Adams Express Company	Freight charges, March, April, and May, 1887.	178.55
30	264	G. F. Becker	Salary, March 1 to June 30, 1887	1,844.40
30	265	A. F. Dunnington	Services, June, 1887	115.40
30	266	Z. D. Gilman	Photographic outfit	129.60
30	267	Pay-roll of employés	Services, June, 1887	278.80
30	268	Lawrence C. Johnson	do	115.40
30	269	H. R. Geiger	do	128.60
30	270	J. Henry Blake	do	148.80
30	271	Pay-roll of employés	do	148.80
30	272	O. C. Marsh	do	829.70
30	273	A. Hermann	Services, April, May, and June, 1887	225.00
30	274	T. A. Bostwick	do	225.00
30	275	E. H. Barbour	do	850.00
30	276	Leo Lesquereux	Services, June, 1887	75.00
30	277	Charles F. Kendall	Storage of public property	24.00
30	278	S. H. Friendly	do	15.75
30	279	W. F. Walker	Care and forage of public animals	90.00
30	280	C. C. Vermeule	Traveling expenses	32.08
30	281	C. Kirchhoff, jr	Services	800.00
30	282	Sumner H. Bodfish	Services, June, 1887	164.80

Abstract of disbursements made by John D. McChesney, etc.—Continued.

Date.	No. of voucher.	To whom paid.	For what paid.	Amount.
1887.				
June 30	283	George W. Shutt	Services, June, 1887	$247.25
30	284	C. W. Hawkins	......do	50.00
30	285	R. B. Cameron	......do	50.00
30	286	Pay-roll of employés	......do	855.55
30	287	......do	......do	398.20
30	288	......do	......do	1,100.50
30	289	......do	......do	2,916.80
30	290	......do	......do	2,554.24
30	291	......do	......do	3,289.35
30	292	W. N. Merriam	Services, May and June, 1887	234.60
30	293	William J. Shaw	Services, June, 1887	50.00
30	294	S. D. Howie	......do	110.00
30	295	Charles Oley	......do	90.00
30	296	W. S. Bayley	......do	60.00
30	297	Pay-roll of employés	......do	256.13
30	298	Samuel Lightfoot	Services, June 17 to 30, 1887	23.33
30	299	Washington Gas light Company	Gas for June, 1887	92.89
30	300	Chesapeake and Potomac Telephone Company.	Telephone service to June 30, 1887	155.50
30	301	Samuel H. Scudder	Services, June, 1887	206.00
30	302	N. S. Shaler	......do	260.00
30	303	Robert Robertson	......do	50.00
30	304	Collier Cobb	......do	50.00
30	305	W. F. Ganong	......do	40.00
30	306	T. C. Chamberlin	......do	296.70
30	307	New York and New England Railroad.	Transportation of the Director	11.45
30	308	B. F. McCaully & Co	1 horse	250.00
30	309	......do	Care and forage of public animals	51.00
30	310	James G. Bowen	......do	72.95
30	311	R. R. Thornton	Washing towels	5.35
30	312	W. S. Bayley	Traveling expenses	86.54
30	313	I. P. Adams	Storage of public property	15.00
30	314	O. H. P. Clark	Pasturage of public animals	5.00
30	315	George M. Turner	Services, May 16 to June 16, 1887	50.00
30	316	Arthur Keith	Services, June 21 to 30, 1887	16.67
30	317	Fielding Burns	Traveling expenses	38.85
30	318	Baltimore and Ohio Telegraph Company.	Telegrams, May, 1887	.55
30	319	National Press Intelligence Company.	Services	5.45
30	320	J. B. Smith	Field material	7.01
30	321	......do	......do	7.00
30	322	......do	Subsistence	14.85
30	323	Z. D. Gilman	Laboratory supplies	8.60
30	324	Frank Leverett	Services, January 1 to May 1, 1887	225.00
30	325	J. S. Topham	Field material	30.00
30	326	Lutz & Bro	Office supplies	6.25
30	327	Hume, Cleary & Co	......do	2.00
30	328	M. W. Beveridge	......do	2.39
30	329	Easton & Rupp	......do	3.00
30	330	Lawrence C. Johnson	Traveling expenses	76.05
30	331	S. J. Haislett	Field material	23.50
30	332	John Brinkinbine	Pay, February 26 to June 1, 1887	100.00
30	333	William H. Herron	Services, June, 1887	49.50
30	334	Fred A. Schmidt	Artist's material	1.60
30	335	Royce & Marean	Electric material	13.41
30	336	George H. Eldridge	Services, June 21 to 30, 1887	49.40
30	337	S. F. Emmons	......do	109.89
30	338	W. H. Morrison	Publications	44.00
30	339	W. C. Day	Services, May 2 to June 1, 1887	150.00
30	340	W. H. Walmsley & Co	Photographic supplies	2.40
30	341	I. C. Russell	Cash paid for miscellaneous field expenses	37.76
30	342	George F. Kunz	Services, May 2 to June 1, 1887	80.00
30	343	Bailey Willis	Cash paid for miscellaneous field expenses.	94.56
30	344	Warren Upham	Services, June, 1887	98.90
30	345	Brown & Sharpe Manufacturing Company.	Repairs to instruments	8.78
30	346	Roland D. Irving	Services, June, 1887	247.25
		Total		65,863.02

Abstract of disbursements made by John D. McChesney, etc.—Continued.

SALARIES, OFFICE GEOLOGICAL SURVEY.

Date.	No. of voucher.	To whom paid.	For what paid.	Amount.
1887.				
April 30	1	Pay-roll of employés	Services, April, 1887	$2,855.15
May 31	2	William S. Fitch	Services, May 25 to 31, 1887	17.31
31	3	Pay-roll of employés	do	2,949.70
June 30	4	do	Services, June, 1887	2,929.35
		Total		8,751.51

Abstract of disbursements made by P. H. Christie, special disbursing agent, U. S. Geological Survey, during the second quarter of 1887.

Date.	No. of voucher.	To whom paid.	For what paid.	Amount.
1887.				
Apr. 30	1	Pay-roll (April)	Services, April, 1887	$2,909.10
20	2	N. B. Dunn	Forage of stock	184.50
30	3	E. M. Harnsberger	do	40.00
30	4	E. M. Nettleton	do	50.00
30	5	J. B. Supler	do	21.00
30	6	W. F. Fling	do	52.00
30	7	Baker & Hall	Storage of property	10.00
May 31	8	Pay-roll (May)	Services, May, 1887	2,849.45
31	9	E. M. Nettleton	Forage of stock	15.00
31	10	E. M. Harnsberger	do	40.00
31	11	J. B. Supler	do	17.00
31	12	W. F. Fling	do	27.80
31	13	N. B. Dunn	do	142.83
31	14	Baker & Hall	Storage of property	10.00
June 24	15	A. E. Wilson	Miscellaneous field expenses	18.40
30	16	Pay-roll (June)	Services, June, 1887	2,602.70
30	17	Henkel & Corpening	Storage of property	3.86
30	18	G. G. Booth	do	16.25
30	19	M. H. Horton	do	7.73
30	20	McCurde Sisters	do	8.00
30	21	Baker & Hall	do	10.00
30	22	N. B. Dunn	Miscellaneous field expenses	30.42
30	23	E. M. Nettleton	Forage of stock	15.00
30	24	J. B. Supler	do	13.00
30	25	E. M. Harnsberger	do	28.00
30	26	W. F. Fling	do	22.00
30	27	N. B. Dunn	do	92.25
		Total		9,236.28

Abstract of disbursements made by Arnold Hague, special disbursing agent, U. S. Geological Survey, during the second quarter of 1887.

Date.	No. of voucher.	To whom paid.	For what paid.	Amount.
1887.				
Apr. 9	1	E. J. Owenhouse	Storage	$15.00
12	2	Chas. H. Stewart	Pasturage	129.72
30	3	Pay-roll of employés	Salaries, April, 1887	684.90
May 31	4	do	Salaries, May, 1887	705.20
June 14	5	Chas. H. Stewart	Pasturage	42.00
24	6	F. C. Phillips	Analysis of gases	135.00
30	7	Pay-roll of employés	Salaries, June, 1887	684.90
30	8	Chas. H. Stewart	Pasturage	56.70
30	9	E. J. Owenhouse	Storage	15.00
30	10	Pay-roll of employés	Salaries, June, 1887	297.34
30	11	Jos. P. Iddings	Traveling expenses	30.00
30	12	A. C. Gill	do	30.59
30	13	W. H. Weed	do	27.35
30	14	Jos. P. Iddings	Miscellaneous expenses	32.28
30	15	S. W. Cook	Field supplies	114.00
30	16	E. J. Owenhouse	Horse	75.00
30	17	do	Field supplies	249.30
30	18	E. A. Rouse	Care and forage of public animals	42.00
30	19	A. Lamme & Co	Field supplies and subsistence	231.36
				3,597.64

Abstract of disbursements made by G. K. Gilbert, disbursing agent, U. S. Geological Survey, during the second quarter of 1887.

Date.	No. of voucher.	To whom paid.	For what paid.	Amount.
1887.				
Apr. 5	1	R. B. Waters	Saddle-bags	$8.00
30	2	G. K. Gilbert	Traveling expenses	164.80
30	3	......do	Services, April 1 to 30, 1887	329.70
May 31	4	......do	Services, May 1 to 31, 1887	340.60
June 15	5	......do	Traveling expenses	61.80
30	6	......do	Services, June 1 to 30, 1887	329.70
				1,229.60

Abstract of disbursements made by R. R. Hawkins, special disbursing agent, U. S. Geological Survey, during the second quarter of 1887.

1887.				
Apr. 1	1	Goldberg, Bowen & Co	Field supplies	$72.21
1	2	......do	......do	23.90
1	3	Neville & Co	......do	9.79
1	4	L. Jones	Cartage	3.50
9	5	H. W. Turner	Field expenditures	23.00
9	6	W. S. Bryan, postmaster	Post-office box-rent	3.00
30	7	Pay-roll	Services	578.50
29	8	Charles McLaren	......do	60.00
30	9	Albion S. Howe	......do	60.00
30	10	H. W. Turner	Field expenditures	14.13
30	11	G. W. Grannis	Rent of rooms	52.66
May 2	12	Frank Barnard & Co	Fuel	3.50
2	13	G. W. Smethhurst	Foraging public animals	41.50
6	14	F. C. Boyce	Services	30.00
11	15	H. L. Howse	Laboratory supplies	15.50
19	16	A. Carlisle & Co	Office and field supplies	31.90
23	17	Eimer & Amend	Laboratory supplies	4.50
26	18	Western Union Telegraph Company	Transmitting telegrams	2.10
31	19	Albion S. Howe	Services, May 1 to 31, 1887	60.00
31	20	Pay-roll	......do	598.00
31	21	H. Davis	Cartage and labor	16.25
June 2	22	Charles McLaren	Services, May 1 to 31, 1887	60.00
2	23	H. W. Turner	Field expenditures	26.23
7	24	......do	Traveling expenses	8.10
10	25	A. Carlisle & Co	Office supplies	9.76
15	26	F. C. Boyce	Services, May 1 to 31, 1887	60.00
15	27	W. Lindgren	Traveling expenses	11.00
15	28	......do	Field expenditures	75.08
18	29	John Taylor & Co	Supplies	57.35
24	30	H. W. Turner	Field expenditures	38.48
29	31	Wells, Fargo & Co	Expressage	30.20
30	32	Pay-roll	Services, June 1 to 30, 1887	578.50
30	33	Albion S. Howe	......do	60.00
30	34	F. C. Boyce	......do	60.00
30	35	John W. Durel	Services, June 6 to 30, 1887	32.00
30	36	Charles McLaren	Services, June 15 to 30, 1887	30.00
30	37	Frank Rader	......do	20.00
30	38	H. W. Turner	Field expenditures	12.50
30	39	R. R. Hawkins	Sundry cash expenditures	114.59
				2,987.68

Abstract of disbursements made by A. O'D. Taylor, jr., special disbursing agent, U. S. Geological Survey, during the second quarter of 1887.

1887.				
Apr. 12	1	Henry Bull, jr	Telephone rent	$11.50
13	2	William Smith	Putting locks, etc., on mineral cases	5.00
15	3	William J. Swinburne	Coal, etc	158.25
15	4	Gustave Hamilton	Two window-shades	2.[illegible]0
16	5	E. and H. T. Anthony & Co	Photographic supplies	19.06
26	6	James A. Easterbrooks	Leather tripod case, etc	4.80
30	7	Raphael Pumpelly	Pay for April, 1887	329.70
30	8	A. O'D. Taylor, jr	......do	98.90
30	9	T. Nelson Dale	......do	125.00
30	10	A. Prescott Baker	Rent for April, 1887	50.00
May 3	11	Raphael Pumpelly	Miscellaneous office expenses	52.10
6	12	Algernon B. Corbin	Stationery supplies	12.44
12	13	T. Nelson Dale	Traveling expenses	13.25
17	14	J. M. K. Southwick	Hardware supplies	25.65

Abstract of disbursements made by A. O'D. Taylor, jr., etc.—Continued.

Date.	No. of voucher.	To whom paid.	For what paid.	Amount.
1887.				
May 18	15	Adams Express Company	Express charges	$6.75
21	16	T. Nelson Dale	Traveling expenses	11.15
23	17	Richard Bliss	Bibliographical work	42.30
31	18	Josiah Pierce, jr	Pay for April, 1887	100.00
31	19	......do	Traveling expenses	94.65
31	20	Raphael Pumpelly	......do	132.45
31	21	......do	Pay for May, 1887	340.60
31	22	A. O'D. Taylor, jr	......do	102.20
31	23	T. Nelson Dale	......do	150.00
31	24	A. Prescott Baker	Rent for May, 1887	50.00
31	25	T. B. Brooks	Three months' rent of office at Bainbridge, Ga.	40.00
June 7	26	J. Eliot Wolff	Pay to May 31, 1887	52.75
7	27	T. Nelson Dale	Traveling expenses	12.09
16	28	George E. Littlefield	Books	14.68
18	29	T. Nelson Dale	Traveling expenses	14.75
27	30	G. P. Putnam's Sons	Wrapping paper	5.75
30	31	Newport Water Works	Water, supplied to June 30, 1887	9.00
30	32	Henry Bull, jr	Telephone rent	11.50
30	33	A. Prescott Baker	Rent to June 30, 1887	50.00
30	34	Raphael Pumpelly	Pay to June 30, 1887	329.70
30	35	A. O'D. Taylor, jr	......do	98.90
30	36	J. Eliot Wolff	......do	75.82
30	37	T. Nelson Dale	......do	150.00
30	38	Adams Express Company	Express charges	6.30
30	39	Richard Bliss	Bibliographical work	32.70
30	40	Nathan Barker	Carpentry work	43.05
30	41	Charles E. Hammett, jr	Stationery	3.27
30	42	T. B. Brooks	Use of Brooks's collection	80.00
30	43	John Pumpelly	Rent of instruments	90.00
30	44	William H. Hobbs	Pay to June 30, 1887	6.65
30	45	J. Eliot Wolff	Flagg's bill for team hire	20.00
30	46	T. Nelson Dale	Traveling expenses	9.97
30	47	J. Eliot Wolff	......do	24.31
30	48	F. E. Swift	Board bill	30.00
30	49	Raphael Pumpelly	Miscellaneous expenses	104.26
30	50	......do	Traveling expenses	69.75
30	51	H. L. Smyth	......do	18.71
30	52	W. M. Davis	Pay to June 30, 1887	50.00
30	53	......do	Traveling expenses	35.00
30	54	Raphael Pumpelly	......do	4.44
30	55	......do	Miscellaneous expenses	14.54
				3,396.09

Abstract of disbursements made by Alfred M. Rogers, disbursing agent, U. S. Geological Survey, during the second quarter of 1887.

Date.	No. of voucher.	To whom paid.	For what paid.	Amount.
1887.				
May 2	1	McElroy & Fulwider	Field expenses	$2.50
Apr. 30	2	Pay-roll	Services, April, 1887	679.10
May 3	3	William Ainsworth	Repair of instruments	2.50
31	4	Pay-roll	Services, May, 1887	616.96
June 1	5	C. A. Kendrick	Field supplies and expenses	45.30
2	6	Chain, Hardy & Co	Stationery	8.10
13	7	Callaway Bros. & Dingwell	Laboratory material	3.50
16	8	Kerstins & Peters	Office supplies	2.05
16	9	Denver Fire-clay Company	Laboratory material	3.25
21	10	James W. Queen & Co	......do	5.10
16	11	E. Besley & Co	Stationery	1.50
30	12	Sam P. Barbee	Rent	157.50
30	13	Peter McCourt	......do	150.00
30	14	The Denver Water Company	Laboratory material	37.50
30	15	S. F. Emmons	Pay, April 1, 1887, to June 20, 1887, inclusive.	890.08
30	16	Pay-roll	Services, June, 1887	327.30
30	17	C. A. Roberts & Co	Office supplies	1.10
30	18	Pacific Express Company	Transportation of property	9.60
30	19	R. W. Speer	Correspondence	2.50
30	20	Denver Gas Company	Laboratory material	10.80
30	21	H. E. Sylvester & Co	Office supplies	7.50
30	22	Dan Phillips	Services	14.75
30	23	Margaret Hodges	......do	2.58
30	24	Denver Fire-clay Company	Laboratory material	16.90
				2,997.97

Abstract of disbursements made by James C. Pilling, special disbursing agent, U. S. Geological Survey, during the second quarter of 1887.

Date.	No. of voucher.	To whom paid.	For what paid.	Amount.
1887.				
May 20	1	Charles S. Fechheimer	Blankets	$34.00
20	2	Neville & Co	Duck-cloth	9.00
21	3	Wells, Fargo & Co	Expressage	9.45
21	4	A. F. Dunnington	Traveling expenses	126.45
21	5	Redick H. McKee	......do	116.20
21	6	H. M. Wilson	......do	117.75
21	7	......do	Field expenses	43.90
26	8	E. C. Ryan	Traveling expenses	126.90
26	9	Eugene Ricksecker	......do	145.95
27	10	Charles W. Howell	Care and forage of stock	38.55
27	11	Fred J. Knight	Traveling expenses	126.05
28	12	Thompson & Co	Rations, supplies	6.50
28	13	Thompson & Stephenson	Forage	57.85
28	14	George H. Curry	Rations, subsistence	84.63
28	15	James G. Marshall	Services as teamster, May 28, 1887	1.50
28	16	D. R. and E. V. Mills	Supplies	6.55
28	17	Wells, Fargo & Co	Expressage	34.35
28	18	H. C. Myer	Hardware	14.50
28	19	Western Union Telegraph Company.	Telegraph service	3.92
31	20	Jacob Thompson	Storage	56.00
31	21	Eugene Ricksecker	Salary, May 1 to 31, 1887	119.20
31	22	Fred J. Knight	Salary, May 16 to 31, 1887	70.27
31	23	Charles W. Howell	Salary as packer, May 1 to 31, 1887	60.00
31	24	E. C. Ryan	Salary for May, 1887	50.00
29	25	Denier & Bridge	Board and lodging for employés	15.00
31	26	......do	Board and lodging of E. C. Ryan	8.00
June 3	27	Redick H. McKee	Field expenses	15.50
3	28	......do	Salary for May, 1887	85.20
3	29	J. H. Boring	Services for May, 1887	45.00
3	30	H. M. Wilson	Salary for May, 1887	153.40
3	31	......do	Field expenses	79.77
3	32	A. H. Thompson	Traveling expenses	189.15
3	33	James C. Pilling	......do	136.65
6	34	A. F. Dunnington	Field expenses	29.50
4	35	James C. Pilling	Re-imbursement	1.00
14	36	H. M. Wilson	Field expenses	53.85
16	37	Arthur Watts	Services as packer, May 1 to 31, 1887.	75.00
16	38	Wells, Fargo & Co	Expressage	10.80
16	39	W. S. Woodside	Camp supplies	2.20
16	40	W. H. Hulvey	Supplies	7.20
17	41	Navajo Jake	Services	12.00
30	42	H. M. Wilson	Salary for June	148.30
30	43	Redick H. McKee	......do	82.40
30	44	J. H. Boring	Services as packer, June 1 to 30, 1887.	45.00
30	45	L. H. Phillips	Forage, etc	94.39
30	46	Pay-roll of employés	Services for June, 1887	281.90
30	47	......do	......do	255.40
30	48	E. C. Ryan	Salary for June, 1887	50.00
30	49	Amos Scott	Services as packer, April, May, June, 1887.	180.00
30	50	Redick H. McKee	Traveling expenses	57.00
30	51	A. F. Dunnington	Field expenses	36.25
30	52	H. M. Wilson	......do	50.09
30	53	J. C. Pierce	Storage	16.00
30	54	A. H. Thompson	Services, June, 1887	222.50
30	55	H. M. Wilson	Field expenses	74.15
30	56	Redick H. McKee	.....do	47.25
30	57	A. P. Davis	Traveling expenses	53.75
30	58	Arthur Watts	Salary for June, 1887	75.00
30	59	James C. Pilling	Traveling expenses	187.08
30	60	A. H. Thompson	......do	202.88
30	61	Eugene Ricksecker	Field expenses	58.24
30	62	Redick H. McKee	......do	24.55
30	63	E. J. Owenhouse	Storage	40.00
30	64	H. M. Wilson	Field expenses	57.61
30	65	A. F. Dunnington	......do	40.85
30	66	B. H. Gilman	Forage	21.89
30	67	A. F. Dunnington	Services as assistant, June 13 and 14, 1887.	5.00
30	68	A. P. Anderson	Forage and supplies	43.72
30	69	A. T. Kyler, jr	Care of public animals	66.02
30	70	Charles W. Howell	Services, June, 1887	60.00
30	71	Fred J. Knight	Field expenses	26.00
30	72	......do	......do	45.07
			Total	4,976.98

Abstract of disbursements made by John D. McChesney, chief disbursing clerk, U. S. Geological Survey, during the third quarter of 1887.

SUPPLEMENTAL TO JUNE 30, 1887.

Date.	No. of voucher.	To whom paid.	For what paid.	Amount.
1887.				
July 12	1	Charles S. Cudlip	Photographic supplies	$293.50
14	2	Charles D. Walcott	Services, June, 1887	164.80
14	3	Appropriations for contingent expenses Department of the Interior, fiscal year 1886-'87.	Miscellaneous supplies	168.75
14	4	Mutual District Messenger Company.	Rental of night watch	5.00
20	5	Charles D. Walcott	Traveling expenses	56.91
20	6	L. G. Eakins	Services, June 21 to 30, 1887	32.97
20	7	C. W. Cross	......do	49.45
20	8	A. M. Rogers	......do	41.21
20	9	Joseph Kenney	Services, May 11 to 24, 1887	20.32
20	10	Eimer & Amend	Laboratory material and supplies	34.85
20	11	Keuffel & Esser	Drawing materials	106.40
20	12	New York and New England Railroad.	Transportation of assistants	24.61
20	13	George T. Wright	Services, July 1, 1886, to June 30, 1887	35.00
21	14	James W. Queen & Co	Instruments and repairs	70.14
21	15	W. & L. E. Gurley	......do	20.64
22	16	H. R. Geiger	Traveling expenses	26.67
22	17	Pennsylvania Railroad Company	Transportation of assistants	49.00
22	18	Bausch & Lamb Optical Company.	A micrometer	2.25
22	19	C. R. Van Hise	Services between June 1 and 30, 1887	50.00
22	20	George H. Williams	Services between February 15 and June 30, 1887.	207.50
22	21	Northern Pacific Railroad Company.	Transportation of assistants	147.35
23	22	Charles G. Yale	Services, January 1 to June 30, 1887	300.00
23	23	L. C. Wooster	......do	96.00
23	24	Wycoff, Seamans & Benedict	Rental of typewriter	9.78
25	25	Elliot P. Hough	Traveling expenses	27.50
25	26	Great Falls Ice Company	Ice, April, May, and June, 1887	43.94
25	27	E. E. Jackson & Co	Office and field supplies	52.83
25	28	W. M. Shuster & Sons	Office supplies	41.37
25	29	Edward J. Hannan	Repairs to laboratory	3.50
25	30	Robert Beale	Publications	4.50
25	31	F. A. Belt	Material for molding	1.00
25	32	New York Central and Hudson River Railroad.	Transportation of assistants	62.00
29	33	Washington B. Williams	Field materials	4.32
Aug. 1	34	R. S. Tarr	Services, April 1 to 12, 1887	30.00
2	35	Edward J. Hannan	Laboratory repairs	3.50
2	36	J. B. Smith	Field subsistence, etc	44.95
3	37	J. B. Supler	Veterinary services	10.00
3	38	C. W. Hall	Services, July 1, 1886, to June 30, 1887	126.00
3	39	William D. Castle	Office supplies and repairs	3.75
3	40	George Ryneal, jr	Office and topographical supplies	8.25
3	41	Western Union Telegraph Company.	Telegrams for June, 1887	39.25
3	42	W. H. Lowdermilk & Co	Publications	232.95
4	43	W. M. Chauvenet	Pay, May and June, 1887	100.00
4	44	R. P. Whitfield	Drawings and description of fossils	402.00
4	45	......do	......do	235.00
8	46	John F. Paret	Ink pad for rubber stamp	.75
8	47	......do	Office supplies	10.20
8	48	William H. Hobbs	Services, May 2 to 6, 1887	15.00
8	49	Ralph S. Tarr	Services, June 1 to 29, 1887	81.00
8	50	W. S. Merrill	Services, May 25 to June 25, 1887	17.00
8	51	Denver and Rio Grande Railroad Company.	Freight charges	10.49
9	52	Atlantic and Pacific Railroad	Transportation of assistants	8.75
9	53	Gustav E. Stechert	Publications	37.45
11	54	R. P. Whitfield	Drawings and description of fossils	277.00
17	55	John C. Parker	Office supplies	2.00
17	56	Bailey Willis	Traveling expenses	19.95
17	57	Arthur Keith	......do	12.87
17	58	Robert Robertson	......do	42.60
17	59	N. S. Shaler	......do	265.80
17	60	Fremont, Elkhorn and Missouri Valley Railroad.	Freight charges	6.40
24	61	A. M. Rogers	Services, June 14 to 20, 1887	28.32
24	62	Henry J. Green	Instruments, etc	534.55
24	63	Julius Bien & Co	Maps	126.65
Sept. 2	64	George Ryneal, jr	Artists' material, etc	5.30
2	65	C. R. Van Hise	Traveling expenses	43.13

Abstract of disbursements made by John D. McChesney, etc.—Continued.

Date.	No. of voucher.	To whom paid.	For what paid.	Amount.
1887.				
Sept. 2	66	W. S. Bayley	Traveling expenses	$67.56
2	67	Warren Upham	......do	70.75
2	68	Collier Cobb	......do	86.71
2	69	Baltimore and Ohio Railroad Company.	Transportation of assistants	14.20
2	70	W. B. Moses & Son	Field and office material	5.48
2	71	Robert Boyd	Field material	55.07
8	72	Heinrick Lesser	Publications	5.58
8	73	F. A. Brockhaus	......do	19.33
8	74	Dulan & Co	......do	61.56
8	75	John Wheldon	......do	19.46
8	76	Citizens' National Bank	Bills of exchange	1.48
9	77	R. D. Irving	Field expenses	2.00
13	78	L. H. Schneider's Son	Laboratory and office supplies	56.37
15	79	Adams Express Company	Freight charges	77.80
15	80	Z. D. Gilman	Supplies for repairs to instruments, etc.	2.35
20	81	Baltimore and Ohio Railroad	Freight charges	72.47
				5,604.04
			Total	495,727.64

RECAPITULATION.

		Geological Survey.	Salaries, office Director.	Total.
Appropriation fiscal year ending June 30, 1887		$467,700.00	$35,540.00	$503,240.00
Expended as per abstracts herewith		460,746.70	34,980.94	495,727.64
Bonded railroad account settled at United States Treasury:				
Freight	$659.57			
Transportation of assistants	1,494.05			
		2,153.62	....	2,153.62
Balance on hand		4,799.68	559.06	5,358.74

DEPARTMENT OF THE INTERIOR, UNITED STATES GEOLOGICAL SURVEY.

PAPERS ACCOMPANYING THE ANNUAL REPORT

OF THE

DIRECTOR OF THE U. S. GEOLOGICAL SURVEY

FOR THE

FISCAL YEAR ENDING JUNE 30, 1887.

QUATERNARY HISTORY OF MONO VALLEY, CALIFORNIA.

BY

ISRAEL C. RUSSELL.

CONTENTS

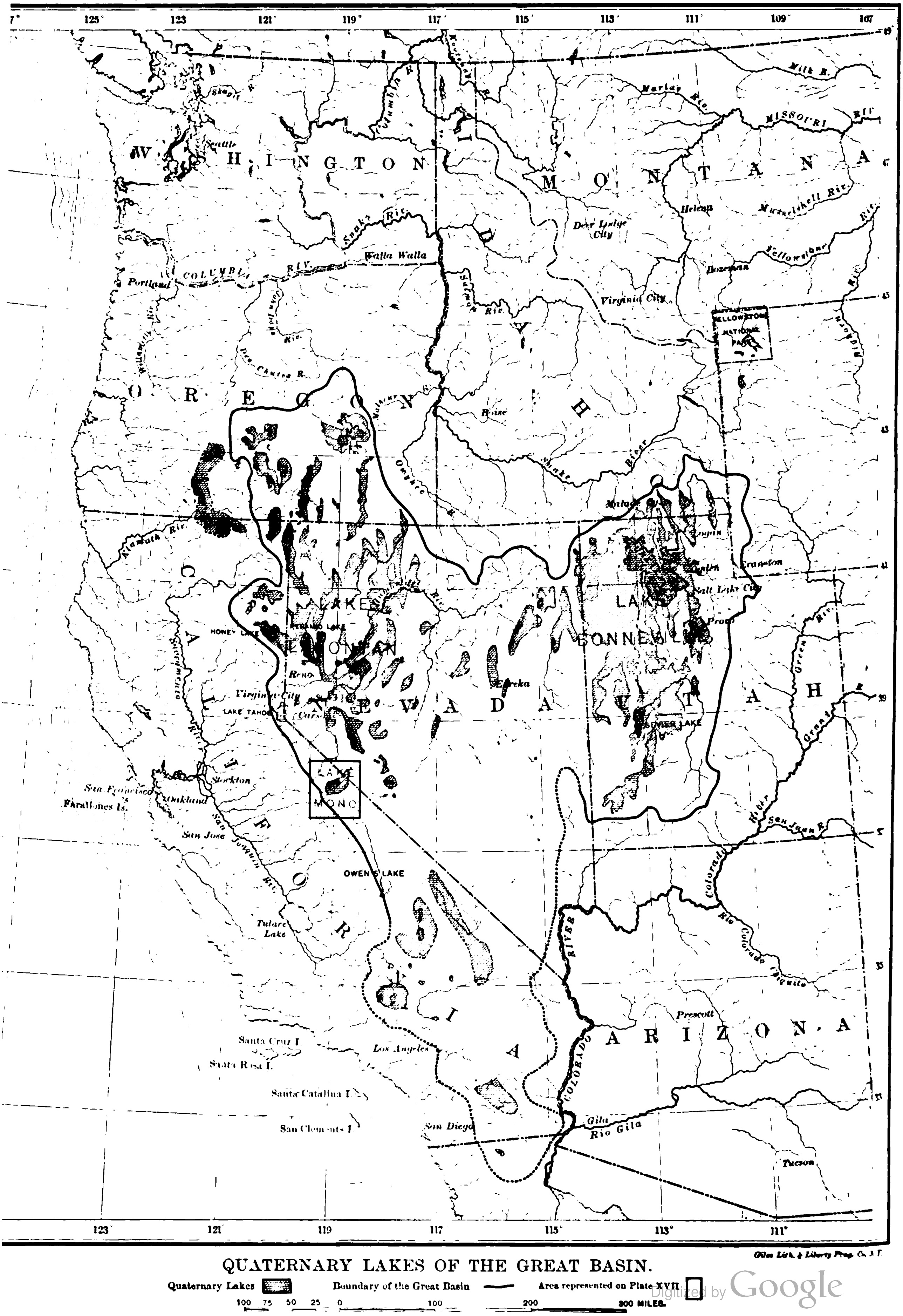
ILLUSTRATIONS

PREFATORY NOTE.

The explorations reported in this paper were incidental to the study of Lake Lahontan, an account of which was published in the Third Annual Report and in Monograph No. XI of this Survey.

I first entered Mono Valley in the spring of 1881, and became acquainted with the more prominent features of its Quaternary history, but the detailed study of the region was left unfinished, in order to continue the exploration of Lahontan Basin, which was the immediate object of the reconnaissance. Late in the fall of the following year, after closing the study of Lake Lahontan, I returned to Mono Valley and endeavored to finish the observations begun the previous year, but the storms of winter compelled a postponement of the undertaking. During my second visit I was accompanied by Willard D. Johnson, who began a topographic survey of the basin, and by W J McGee and George M. Wright, as geological aids. To each of these gentlemen I am indebted for much valuable assistance. In the summer of 1883 I resumed my studies about Lake Mono, accompanied by Mr. Johnson, who devoted his whole time to the completion of the topographic survey of the basin, and by J. B. Bernadou, as general assistant. I am especially indebted to Mr. Bernadou for field sketches which have been redrawn by De Lancey W. Gill and form Pls. XVIII and XXXIX.

The present paper, like the reports on Lake Lahontan previously published, is a contribution to the Quaternary history of the Great Basin. This work has been carried out under the direction of G. K. Gilbert, to whom is due a very large share of whatever value it may possess. Mr. Gilbert paid a brief visit to Mono Valley in 1883, and made himself familiar with many of the facts narrated in the present paper. He has also read these pages previous to their publication and has generously given me the benefit of his criticism.



Giles Lith. & Liberty Prtg. Co. N.Y.

QUATERNARY LAKES OF THE GREAT BASIN.

Quaternary Lakes — Boundary of the Great Basin — Area represented on Plate XVII

100 75 50 25 0 100 200 300 MILES.

QUATERNARY HISTORY OF MONO VALLEY, CALIFORNIA.

By Israel C. Russell.

THE MONO BASIN.

Lake Mono is situated in east-central California, within a few miles of the California-Nevada boundary. The 38th parallel and the 119th meridian intersect in the center of the lake. It lies at the eastern base of the Sierra Nevada, and its drainage area forms one of the many independent hydrographic basins into which the vast region included between the Rocky Mountains and the Sierra Nevada, known as the Great Basin, is divided. The western rim of its drainage area, formed by the crest line of the Sierra Nevada coincides for thirty-six miles with the western margin of the Great Basin.

The present lake and its maximum extension during the Quaternary period of geological history are represented on the accompanying maps (Pls. XVII, XVIII) together with the limits of its drainage area or hydrographic basin, which we designate the Mono basin.

Situated at the junction of two well defined and strongly contrasted geographic provinces, the Mono basin partakes of leading characteristics of each. It is remarkable for its diversity of topography, its varied and striking contrasts of scenery, its wide range of climate, and corresponding variations of flora. Besides these more obvious characteristics the basin has a varied geological history, the later chapters of which are of fascinating interest at least to some readers, and can be read with unusual facility.

Lake Mono is 6,380 feet above the sea. The lowest pass[1] in the serrate mountain crest along its western border is 3,000 feet above its surface; the highest peaks that overshadow it rise more than 6,000 feet above the level of the lake.[2] The eastern portion of the basin

[1] The divide at the head of the south fork of Leevining Creek.

[2] While preparing the maps accompanying this report, the elevations of the following localities about Mono Valley were computed by W. D. Johnson from triangulations made by himself and connected with Mt. Conness, the height of which was kindly furnished by the U. S. Coast and Geodetic Survey:

	Feet.
McBride Peak (north end White Mountain range)	13,432
Mt. Ritter	13,072

partakes of the character of the arid region of interior drainage of which it forms a part, and includes valleys covered with sage-brush and rugged mountain slopes, which are but scantily clothed with cedar and piñon. The tone of the landscape in this portion of the basin is gray and russet-brown, characteristic of the desert. Over its entire area no running water can be found during the greater part of the year, and the region is consequently silent and lifeless. To one reared under more humid skies this portion of the Mono basin would appear a veritable desert, but that it is not really a desert is shown by the fact that it produces nutritious bunch grass among the clumps of sage brush in sufficient abundance to afford pasturage for a few cattle and horses.

The southwestern border of the basin includes magnificent mountains that are clothed in favored places with forests of pine. The highest peaks reach far above the timber line and bear a varied and beautiful Alpine flora. In the cañons that descend from the snow-fields and miniature glaciers about the higher summits, the rush of creeks and rills is heard throughout the year. The eastern and western portions of this single hydrographic basin are fragments of two distinct geographic provinces. One has the desolation and solitude of the Sahara, the other the rugged grandeur of the Pyrenees.

Few journeys of equal length could present greater diversity in all the elements of scenery than a single summer day's ride from the parched and desert plains bordering Lake Mono on the north, to the crest of the mountain mass that fills the horizon to the west and southwest of the lake. As it has been my fortune to make this ride a number of times in various seasons, I will ask the reader to go with me in fancy throughout the area we are to study and ascend Mt. Dana. During this ride we may become acquainted with the more interesting features of the region as well as with some of the geological problems it offers for solution; and from the top of the peak,

	Feet.
Mt. Lyell	13,042
Mt. Dana	12,992
Mt. Conness	12,553
Dunderberg Peak	12,320
Mt. Warren	12,270
Glass Mountain (north of Adobe Meadows)	11,127
Highest point of Mono Craters	9,137
Standard Hoisting Works (Bodie)	8,722
Bodie (main street)	8,335
Aurora, post-office	7,340
Divide on road between Mono Valley and Adobe Meadows	7,160
Level of highest beach line in Mono Valley	7,062
Thompson's ranch (Owen's River Valley)	7,252
Shaw's ranch (Adobe Meadows)	6,495
Bridgeport, post-office	6,402
Lake Mono (surface; summer of 1883)	6,380

named in honor of one of our most distinguished geologists, we may overlook the entire basin with which we are specially concerned, and, at the same time, obtain a magnificent view of the wonderful scenery of the High Sierra.

The most practicable route for reaching Lake Mono from the East is by rail to Reno, Nev., thence by the Carson and Colorado Railroad to the town of Hawthorne, situated at the south end of Walker Lake, and thence by a well-constructed mountain road which winds and zigzags up the steep eastern slope of the Walker River or Wassuc Mountains, at the foot of which Hawthorne is situated. This road is a monument of western enterprise, and owes its construction mainly to the development of the rich silver mines of Bodie.

At present there is no railroad connection with Mono Valley; we therefore make the journey from Hawthorne to Aurora by stage. Passing up the fine highway mentioned to the crest of the Walker River range, we obtain a characteristic, wide-reaching view of the desert scenery of Nevada. Should this ascent be made near sunset, when the deserts are shrouded in purple shadows and the rugged peaks above are drawn in strong outlines on a sky of amber, merging upward into purple and blue and becoming almost black at the zenith, the traveler will have a peculiarly beautiful picture impressed on his mind which time can scarcely efface. On descending toward Aurora, which is situated just outside the border of the hydrographic basin of Lake Mono, the scene changes, and the desolation of the arid scenery of Nevada gives place to the grand mountain topography of California. The lofty peaks and sharp crests of the Sierra Nevada and the Sweetwater Mountains arrest the eye and excite the wonder and admiration of all who have not been long familiar with the magnificence of the High Sierra.

Explorers in the Far West have found that the most practicable method of carrying forward their work is to travel on mule back, the desert character of much of the country and the consequent scarcity of grass and water making the use of horses less satisfactory. From Aurora, therefore, as there are no public conveyances leading through the section we wish to examine, we will continue our journey in the saddle.

Riding eastward from Aurora, just as the rising sun is making the ugliness of that nearly abandoned mining camp only too apparent, we follow a well beaten road which ascends for a mile or two and crosses a low ridge. A change in the drainage, or rather in the slope of the stream channels—for they are dry at least ten months in the year, indicates—to one familiar with the region, that we are within the Mono basin. A mile down the road we come to a small spring which discharges less than a quart of water a minute. We halt at a trough into which the spring water is conducted, to fill our canteens and water our animals. This is the last water we shall find

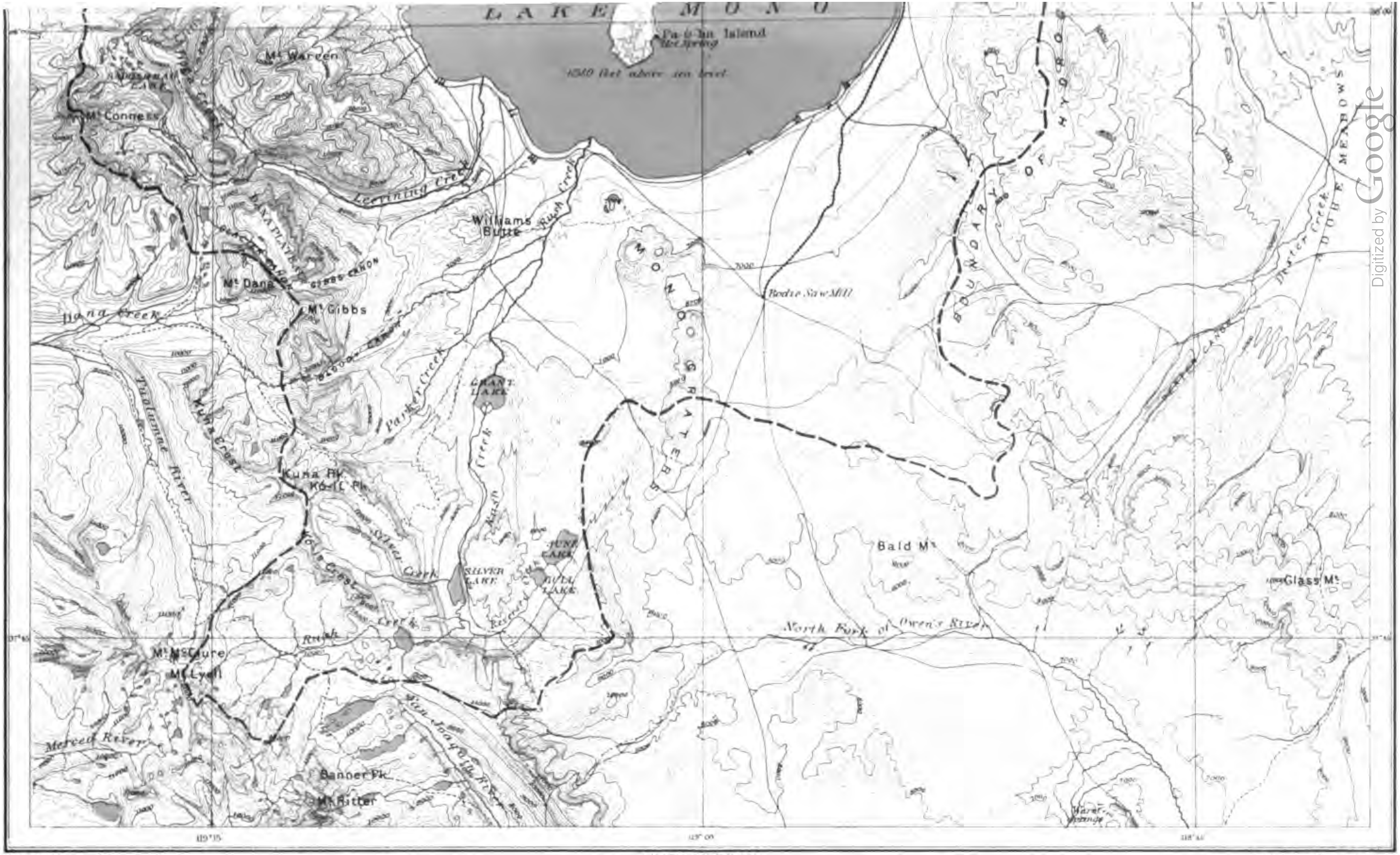
on our road until we reach the shore of Lake Mono, and the last that is fit to drink, with the exception of a few small springs near the east shore of the lake, until we refresh our parched lips in the rushing creeks born of the snow-fields of the High Sierra, now nearly forty miles away.

Riding on, we descend rapidly. The road winds about steep, volcanic hills, and affords glimpses of the desert valleys below and of the cedar-covered mountains to the eastward. From a few commanding points, through a vista of rugged hills, we obtain delightful views of Lake Mono and the white peaks beyond.

Reaching the plain, which we shall call Aurora Valley, after the mining town on the hills above, we find its surface a level-floored desert, scantily clothed with sage-brush and bunch-grass. From obscure terraces about the bases of the hills we are enabled to determine that this was once the bed of a lake. In the lowest part of the basin the water was formerly 250 feet deep. We can trace the ancient water lines with tolerable certainty about the northern border of the basin, and are thus assured that the ancient lake did not overflow in that direction. The only depressions in the rim of the valley which are below the level of the highest of the beaches lead southward into Mono Valley. We shall find, as we proceed, that it was the overflow from Mono Valley which formerly flooded the Aurora basin.

Riding southward we traverse the long, deep pass that attracted our attention from the hills above, connecting Aurora and Mono Valleys. From the peculiar form of this straight, narrow gorge we name it Trench Cañon. Advancing, we observe that the ancient beaches seen about Aurora Valley extend entirely through, as parallel horizontal lines on each side of the trough, at an elevation of about two hundred feet, and are marked in places with tufa deposits. At the south end of Trench Cañon the bottom rises to within eighty feet of the highest of the ancient beaches, and shows evidences of having been eroded by the currents that once set through it. The terraces on either side of the cañon, where it opens out into Mono Valley, are more strongly defined and more numerous than at any other locality thus far seen during our ride.

Gaining the top of a conical butte which rises a mile south of Trench Cañon, we obtain an extended view embracing nearly the entire Mono basin, and are much impressed with the magnificence of the High Sierra which limits the landscape to the south. Mt. Dana, the goal of our journey, stands out boldly on the highest part of the range that is well in view and may be distinguished from its neighbors by its gable-like profile. It is distant over eight leagues, but it seems scarcely more than as many miles away. In front of us stretches a sloping, featureless plain, with scattered clumps of cedars and dunes of drifting sand.



W. D. Johnson, Topographer

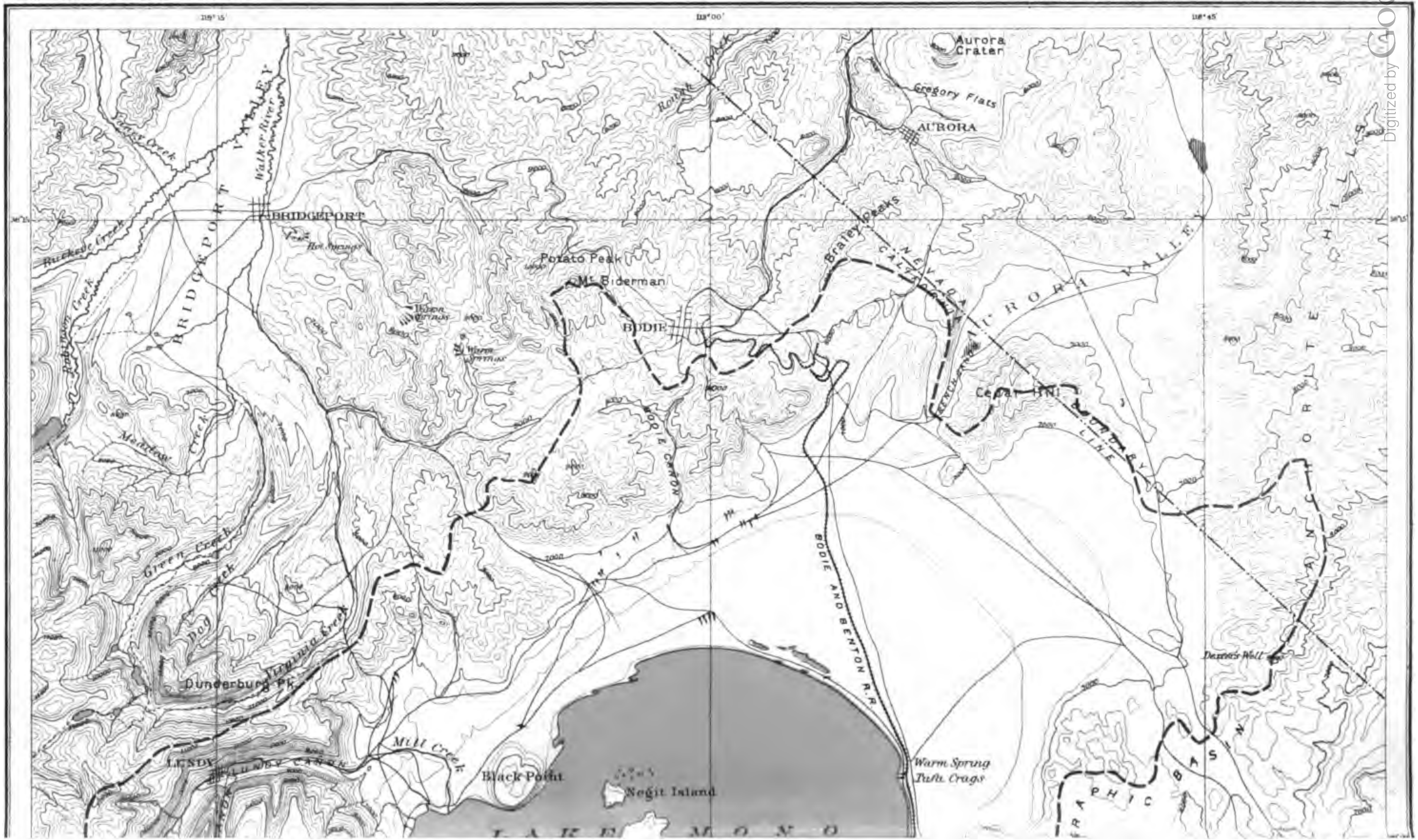
I. C. Russell, Geologist.

HYDROGRAPHIC BASIN OF LAKE MONO.

Scale 1: 250 000.

5 0 5 10 15 20 miles

Contour interval 200 feet – datum mean sea level.


Aurora Crater
Gregory Flats
AURORA
BRIDGEPORT
BRIDGEPORT VALLEY
Walker River
Buckeye Creek
Robinson Creek
Meadow Creek
Green Creek
Dog Creek
Virginia Creek
Dunderburg Pk.
LUNDY
LUNDY CAÑON
Mill Creek
Hot Springs
Warm Springs
Potato Peak
Mt. Biderman
BODIE
BODIE CAÑON
Braley Peaks
NEVADA CALIFORNIA
BOUNDARY LINE
AURORA VALLEY
Cedar Hill
BODIE AND BENTON R.R.
Black Point
Negit Island
LAKE MONO
Warm Spring
Tufa Crags
Dexter's Well
ANCHORITE HILLS
GRAPHIC BASIN
119°15'
119°00'
118°45'

In the middle distance there rests upon the desert plain what appears to be a wide sheet of burnished metal, so even and brilliant is its surface. It is Lake Mono. At times the waters reflect the mountains beyond with strange distinctness and impress one as being in some way peculiar, but usually their ripples gleam and flash in the sunlight like the waves of ordinary lakes. No one would think from a distant view that the water which seems so bright and enticing is in reality so dense and alkaline that it would quickly cause the death of a traveler who could find no other with which to quench his thirst. It is in truth a Dead Sea, but without the mysterious charm that history, tradition, and religion impart to the similar sea in Palestine. On either side of the lake are bold, rugged hills, rising more than a thousand feet above its surface, which in many lands would be considered worthy of the name of mountains, but are here dwarfed and rendered almost insignificant by the proximity of the High Sierra.

From the commanding station we have attained we can see across the rim of the Mono basin to the southward and obtain a fine view of the White Mountains, one of the most remarkable of the basin ranges. The highest peak in this mountain mass stands out clear and angular against the sky, and is more elevated than the most prominent peaks of the Sierra that are in sight. During the winter and far into the summer, the sides of these mountains are white with snow and appear wonderfully bold and precipitous. In late summer and autumn the snows vanish, and the bare, ruddy-gray mass appears even more lifeless and silent than in winter. Seen through the translucent air of Indian summer, these peaks have an almost supernatural grandeur, and at times, owing to the density of the desert haze about their bases, they seem spectral mountains, huge and indefinite, suspended in mid air.

We pass on down the sloping plain leading to Lake Mono, and after a monotonous ride of ten or twelve miles through sage-brush, over sand dunes, and across ancient lake beaches, reach Warm Springs, on the eastern shore of the lake. When I gained this camping place in the spring of 1881, the only evidence that it had been frequented by man was a trail leading to a spring. A year later I found a railroad crossing the valley, and a station near where I had previously camped. This is the Bodie and Benton Railroad, at present incomplete, which connects Bodie with the pine forests clothing portions of the eastern border of Mono Valley.

Camping near Warm Spring, we may have a bath in the dense waters of the lake and afterward plunge into the deliciously warm spring, now conveniently arranged for bathing. This is one of a number of thermal springs to be found in and about the lake, which will be described as we proceed. Strolling along the shore we find windrows thrown up by the waves, not only of sand and gravel (which

we notice are of volcanic origin and contain fragments of pumice), but also of the larval cases of a fly that inhabits the lake in countless myriads. These larvæ are used by the Piute Indians for food. During the autumn, Indian encampments may be found all about the lake; while women, in picturesque groups, may be seen gathering the food as it is thrown ashore by the waves. The partially dried larvæ, the kernels, are separated from the inclosing cases, the chaff, by winnowing in the wind with the aid of a scoop-shaped basket; they are then tossed into large conical baskets, which the women carry on their backs. Such scenes are not only novel, but add a bit of life and color to a landscape apt to impress one as somewhat dreary and somber.

East of Warm Spring, and a few hundred yards from the shore, are low hills with castellated summits, which at once attract the attention of the geologist by the peculiarities of their forms. These are tufa crags, mainly composed of calcium carbonate, which was deposited from the waters of the lake when it stood much higher than now. On examining some of the masses, where they have been broken and overturned so as to expose their structure, we find that they exhibit three varieties of tufa, deposited one on another. The interior of the deposit is compact and stony in structure, corresponding to the similar material found in the Lahontan basin, and named lithoid tufa. This frequently forms tubular masses that appear to have been precipitated from springs. The second deposit is mainly composed of well formed crystals, and is the mineral known as thinolite. A branching or dendritic variety is also present. These tufa crags and many others of a similar character found in various parts of the basin, will be described in the section of the present paper treating of the chemical history of the lake.

Reaching the topmost crag of the tufa deposit, we pause once more to study the topography of the region we are exploring. We notice especially a series of ancient terraces scoring the eastern border of the valley with long parallel lines. The highest is 672 feet above the level of the present lake, and records the maximum rise of the waters which once flooded the basin. But the feature in the landscape that absorbs the attention and overshadows all else is the vast mountain mass which rises abruptly from the southern border of the lake and forms a portion of the far famed High Sierra. The level plain of water in the foreground, broken by islands in the middle distance and washing the bases of the mountains which form its distant shore, furnishes a base from which to estimate vertical distances and aids one in comprehending the grandeur and magnitude of the scene.

The panorama forming Pl. XVIII was drawn from sketches and photographs taken from this point of view and, although failing to convey anything like the impressions derived from a.tual observation, it will serve as an introduction to the more prominent peaks

in sight. At the right in the picture rises the conical mass of Dunderberg Peak, the summit of which has an elevation of 5,940 feet above the lake. This mountain marks approximately the northwest corner of the hydrographic basin of Lake Mono, and will serve as a surveyor's monument in helping to define the limits of the region to which we at present confine our attention. To the south of Dunderberg Peak is a deep cañon, extending back a number of miles into the mountains. This is the gorge of Mill Creek, or Lundy Cañon, as it is frequently called, from a mining camp which has sprung up within it during the past few years. About seven miles farther south another gap of larger proportions, known as Leevining Cañon, opens out in the mountain face. Between these gorges there rises a mountain, notable for its symmetry and grand proportions, which has been named in honor of G. K. Warren, of the U. S. Engineer Corps. Its culminating peak has an altitude of 5,890 feet above the lake's surface.

Looking up the gorge of Leevining Creek, which bends to the right, we see a curtain wall, formed of nearly perpendicular cliffs and surmounted by a plateau, above which rises the triangular peak of Mt. Dana. The next peak to the south is Mt. Gibbs; its southern slope plunges down many hundreds of feet and forms the left-hand or north wall of Bloody Cañon. Following the crest of the range southward, Kuna and Koip Peaks, together with other mountains scarcely less grand than those we have noticed, but as yet unnamed, attract the attention. Back of these and well within the region of the High Sierra, we catch glimpses of tapering spires and angular crests which are white with snow or glittering with ice throughout the year, and at a glance assure the mountaineer that they are the loftiest peaks in sight. This group includes Mt. Lyell, Mt. Ritter, Mt. McClure, and the Minarets. This is the heart of the High Sierra. From it flow the Tuolumne, Merced, and San Joaquin Rivers, on which depend the life and wealth of the southern portion of the Great Valley of California.

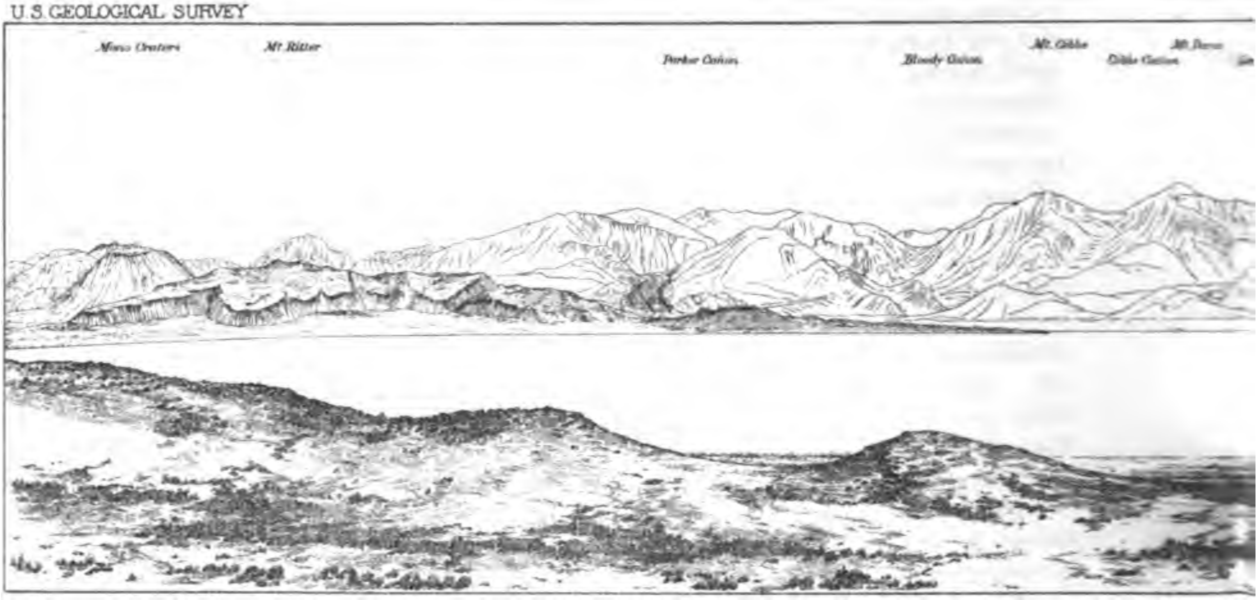
To the left in the panorama and between the observer and the steep face of the Sierra there is a range of volcanic cones that attract the eye, not only on account of their height and the symmetry of their curving slopes of light gray lapilli, but also because they form so striking an exception to the prevailing mountain forms in view. These are the Mono Craters. So perfect are their shapes and so fresh is their appearance that the eye lingers about their summits in half expectation of seeing wreaths of vapor or the lurid light of molten lava ascending from their throats. They have been long extinct, as measured by years, and their summits are cold, but to the geologist their formation was an event of yesterday. They are the youngest mountains in the field of view. Their last eruption took place after the glaciers had retreated up the cañons of the

Sierra. They are also, in part, more recent than the ancient beaches to be seen about the border of the valley, which record former high water stages of Lake Mono.

This range of craters is about ten miles long, and extends beyond the borders of the valley in which we stand. Each of the great cones forming the center of the mass has an elevation of nearly three thousand feet above the lake, and to the right and left are many others of smaller size. The craters are composed throughout of acidic lava, which occurs as compact obsidian or volcanic glass, and at times forms coulées three or four hundred feet thick; or takes the form of scoriæ and pumice, so light that it floats on water. A complete gradation from compact glass to white, froth-like pumice may be observed at many places about the cones. Much of the material forming those extinct volcanoes was extruded in broken fragments, known as lapilli, which fell about the points of eruption and built up the symmetric cones that are such a conspicuous feature in the range. Still finer material termed volcanic dust was blown out with stupendous force and wafted by the winds far and wide over the adjacent mountains and valleys. About the western base of the craters a dark forest of pine stretches away to the left, forming a marked contrast to the lifeless pile of volcanic rock above, on which scarcely a plant has taken root.

Such, in brief, are the elements of the picture that the observer from the tufa crags near Warm Spring has spread before him. No prosaic description, however, can portray the grandeur of fifty miles of rugged mountains, rising beyond a placid lake in which each sharply-cut peak, each shadowy precipice, and each purple gorge is reflected. Nor is it possible to bring to these pages the wonderful transparency of the dry atmosphere of California or the gorgeous coloring of the background against which the mountains repose at sunset.

It has been my fortune to observe the High Sierra from the northern shore of Lake Mono in various seasons and in all shades of illumination that day and night afford. During the summer the range is mostly clear of snow, excepting about the Mt. Lyell group; patches remain here and there, however, to impart variety to the bare slopes above the timber line, and a few of the small glaciers still lingering about the higher peaks may be distinguished. As winter approaches, the higher peaks become brilliant with snow, which trails far down the deep gashes in their sides, leaving the lower slopes dark and somber. Again, the whole range is frequently snow-clad in a single night, and in the clear atmosphere that follows a storm each peak and crest and wall of alabaster stands out clear and sharp against the blue sky, with such repose and grandeur and purity that no one can remain in their presence without a feeling of wonder and admiration.



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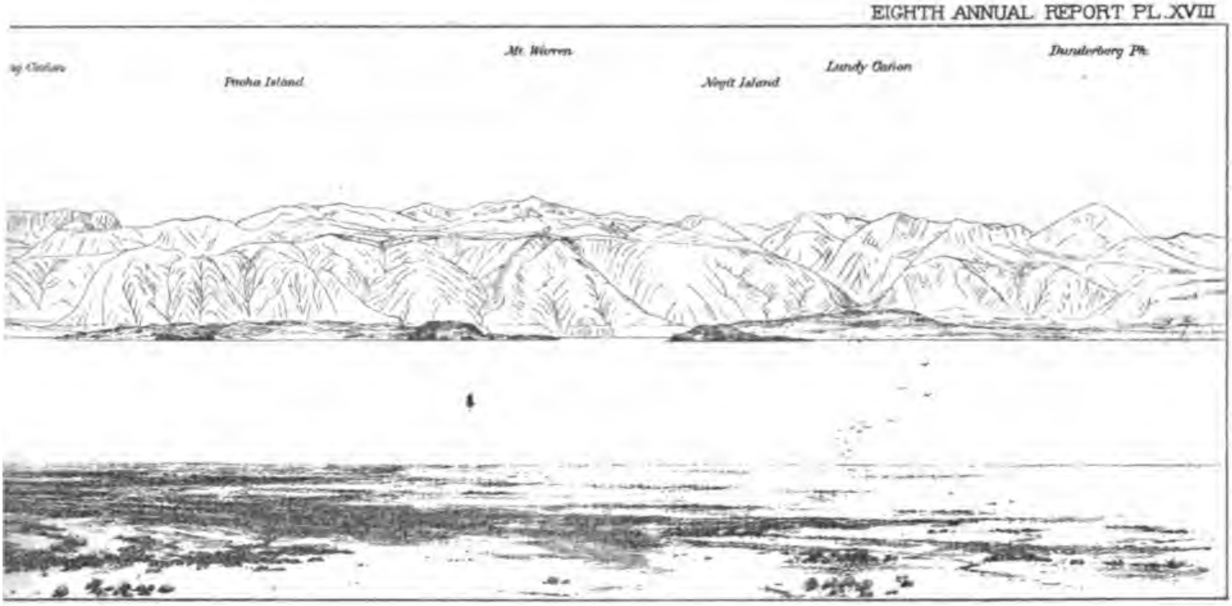


RTH SHORE OF LAKE MONO

Memory recalls but one view of placid waters reflecting snow-covered mountains which equals in grandeur the view of the High Sierra from Lake Mono. That is the picture, familiar to many, of the Bernese Oberland from Lucerne. The High Sierra is most beautiful as seen from the north, in the soft gray light of early morning; in the afternoon and evening, especially during the summer months, a purple haze, peculiar to arid regions, frequently enshrouds the range, obscuring every detail and concealing all traces of inherent color. Sometimes, however, during the summer months, when the sun is low in the west, the mountains are aglow with a luminous purple light, while the crests and spires above, resplendent with sunset tints, are sharply outlined against the evening sky. It is then that the grandest combinations of form and color are to be seen.

There is one feature of the Sierra Nevada that presents itself when the mountains are viewed from the northern shore of Lake Mono which can not fail to impress every geologist who visits the valley. In Pl. XVIII, it will be noticed that there is a terrace-like shoulder all along the eastern slope of Mt. Warren, which may also be seen to the north of Lundy Cañon.[1] This shoulder is in reality a broad terrace much modified by erosion, and it is more conspicuous in nature than in the sketch. The mountain slope rising above it has much the appearance of a sea cliff long exposed to storms and frosts. The elevation of this terrace is in general about 3,300 feet above Lake Mono. It declines as one follows it northward; and north of Lundy Cañon its altitude is not more than 2,600 or 2,800 feet. Its topographic form, especially when the mountains are white with snow, is accented by the dark forests of pine clothing it. Whether this peculiar feature occurs elsewhere along the eastern face of the Sierra Nevada or not, has not been ascertained; but it is so conspicuous at Lake Mono that when the structure of the range is studied it will demand attention.

Perhaps I have detained the reader too long at the shore of Lake Mono, especially if he has become sufficiently interested in our field of study to feel the thrill of anticipation experienced by the explorer when in the presence of a mountain on whose summit he is impatient to stand. I will not linger, therefore, over the every-day experiences of camp life necessitated by the length of our journey, but assume that with the rising sun we are once more in the saddle and continuing along the eastern shore of Lake Mono.

At a distance of a few miles we pass a rude cabin near the lake shore, where Louis Sammonn, the pioneer of the valley, has made his home. There are a few other humble habitations on the southern and western borders of the lake, some of which are surrounded by meadow lands and grain fields of small extent; but nearly the entire valley is without the limit of cultivation for the reason that water can not

[1] A portion of this terrace may be seen in the illustration forming Pl. XX.

be had for irrigation. There was formerly sufficient wild grass in many portions of the basin to support considerable numbers of cattle and sheep; but, owing to overstocking, these natural pastures are now nearly ruined.

If the day chance to be stormy, we shall see an effect of the wind on the waters that but few lakes present. Lake Mono, as already stated, is strongly charged with alkaline salts; when it is agitated by the wind, the waves break into foam which gathers along the leeward shore in a band many rods wide and sometimes several feet thick. Sheets of this tenacious froth are caught up by the wind and driven inland through the desert shrubs in fluffy masses that look like balls of cotton. This peculiar effect of strong winds on alkaline waters is highly picturesque and adds greatly to the beauty of the lake. Owing to the chemical character of its waters, Lake Mono is uninhabited by fishes or mollusks, but it swarms with countless myriads of small crustaceans, known as brine shrimps, and the larvæ of a fly, as mentioned before, are seen about its borders in immense swarms during certain seasons. In autumn and early winter the lake surface is literally darkened with countless numbers of ducks, geese, swans, gulls, grebes, and other aquatic birds, attracted thither by the brine shrimps and larvæ.

After a ride of ten or twelve miles we pass the end of the Mono Craters and may easily climb into one of the smaller bowls of lapilli, within which rise angular crags of obsidian and pumice. Soon after leaving the craters we ford Rush Creek, a clear, bright, rushing stream of cold water, that has its birth in the melting snows of the mountains and is fed by hundreds of rock-inclosed tarns high up on the eastern slope of the Sierra between Mt. Lyell and Mt. Dana. There are two other similar streams entering the lake, one through Lundy Cañon, the other through Leevining Cañon. These, together with numerous springs, constitute the water supply which counterbalances the evaporation from the lake surface.

While riding along the shore of Lake Mono, one's attention is continually attracted to the islands that break the monotony of its surface. The largest of these is remarkable for its light gray color, which makes it appear almost white in comparison with the second in size, which is nearly black. In proceeding with our studies, we shall see that the color of these islands is of geological significance. In seeking for names by which to designate them, it was suggested that their differences in color might be used, but the writer preferred to record some of the poetic words from the language of the aboriginal inhabitants of the valley. On the larger island there are hot springs and orifices through which heated vapors escape, which are among the most interesting features of the basin. In the legends of the Pa-vi-o-osi people, who still inhabit the region in scattered bands, there is a story about diminutive spirits, having long, wavy hair,

that are sometimes seen in the vapor wreaths ascending from hot springs. The word Pa-o-ha,[1] by which these spirits are known, is also used at times to designate hot springs in general. We may therefore name the larger island Paoha Island, in remembrance, perhaps, of the children of the mist that held their revels there on moonlit nights in times long past.

The island second in size we call Negit Island, the name being the Pa-vi-o-osi word for blue-winged goose.

After crossing Rush Creek, we begin the ascent of the sloping plain leading to the base of the Sierra. There are no foot-hills, properly speaking, along this portion of the mountains, but one can ride directly to the base of the great scarp forming the eastern face of the range. The precipitous eastern slope of the Sierra Nevada is determined by an immense fault as previously stated, which can be traced for more than a hundred miles both north and south of Lake Mono. That there has been very recent movement along this fracture is rendered certain by the fresh scarps of displacement which cross moraines, terraces, and alluvial slopes, thus proving that orographic movement has taken place since the withdrawal of the glaciers and since the evaporation of the large lake which formerly filled the valley.

Our goal is the summit of Mt. Dana. The easiest way to attain it is by ascending Bloody Cañon and gaining a position on the western slope of the range conveniently situated for attacking the peak from the south. In the following pages we shall describe somewhat minutely the parallel morainal embankments which extend into the valley from the mouth of Bloody Cañon, but at present we can only notice their more general features. On following up the stream that flows down the cañon and joins Rush Creek, we come to a narrow gap at the end of what appears to be an immense, tongue-shaped accumulation of bowlders and finer débris, prolonged nearly four miles from the cañon mouth. As we advance we find that this mass is in reality composed of two parallel walls with a broad, deep trough or valley between. Once the intervening space was occupied by a glacier which descended from the mountains and built huge lateral moraines on either side, as it advanced into the valley. A detailed map of these moraines may be found on Pl. XXXV, and a view of them as seen from Williams Butte, is given on Pl. XXXVII.

The road between the morainal embankments is steep for a mile or more—the geologist will notice at once that it here crosses crescent-shaped terminal moraines which sweep from side to side of the ancient glacier bed—and then it enters a grassy plain, through which the stream meanders. On the borders of this natural meadow are groves of noble pines, and the side of the southern wall is clothed

[1] The aboriginal words, used in this paper for the first time as proper names, are from manuscript notes on the Indian languages of the West by J. W. Powell.

with mountain mahogany. This is one of the most beautiful camping places in the Mono basin. From it, instructive journeys may be made in all directions. The trough once occupied by ice is here about a thousand feet broad at the bottom, and on either side the moraines are four or five hundred feet high. They increase in magnitude as we approach the mountains, and at the mouth of the cañon rise more than a thousand feet above the lake inclosed between them. After the glacier had retreated, a lake was formed in that portion of its bed which is now a meadow. The drainage was checked by terminal moraines which, as mentioned above, were thrown completely across the trough between the lateral moraines. Subsequently the lake cut down its channel of discharge and was drained dry, leaving its bed a level plain. At the upper end of the meadow we have described, another series of terminal moraines crosses the bed of the ancient glacier and still retains a lake, as indicated on the map forming Pl. XXXV.

Morainal embankments, similar to those at the mouth of Bloody Cañon occur at the extremity of each of the large cañons that have been carved in the southern border of the basin. All these records of ancient ice action will receive attention in the section devoted to the glacial history of the region.

The tourist who wishes to become familiar with the scenery and history of the Mono basin will do well to encamp for several days, and even for weeks, in the beautiful park at the mouth of Bloody Cañon, but we will press on to the pass above.

Following the western shore of the little lake at the foot of the cañon we pass a marshy tract covered with willow clumps and aspens, and at last enter a fine grove of spruce and pine, which conceals from view the cliffs and rocks over which our trail ascends. As we ride along in the grateful shade we come suddenly to a steep ascent and are surprised to find ourselves at the base of the mountains. Immediately the climb begins. The distance to the summit, over which the trail passes, is two miles; in this space the ascent is more than 2,000 feet. For perhaps a mile the trail is not too steep for our sure-footed mules, so we keep our saddles and are carried upwards in a zigzag course. Soon we pass a cascade and come to a rude terrace, above which is another precipice. Here, at the threshold, we have what to the geologist is one of the most peculiar features of the glaciated cañons of the Sierra Nevada, viz: the bottom of the trough is stepped, and presents an alternation of level areas and steep scarps as one ascends. It is a giants' stairway leading up the mountains, in which many of the steps are from two to three hundred feet high.

Pausing on one of the lower terraces to rest our animals we note the features in view. We are in a deep round bottomed trough that leads with a steep grade from the base to the crest of the range. On either hand the walls of naked rock are nearly perpendicular for

many hundreds of feet. At the bases of these precipices there are long slopes of broken and angular stones that have been detached from the cliffs above since the glacial ice was melted. These talus slopes seldom extend completely across the cañon, but leave ledges of quartzite and slate in the central portion entirely unconcealed. The ledges are almost invariably smooth, especially on the side facing up the gorge, and are sometimes so highly polished that they glisten brilliantly in the sunlight. Crossing the ice-polished surfaces are lines and grooves, cut by gravel, sand, and dust, set in the bottom of the ice stream which formerly flowed over them. Looking down the gorge we can see the whole plan of the morainal embankments stretching out like huge arms from the mountain's base and inclosing a forest-bordered lake of lovely blue. Beyond are the soft gray slopes of the Mono Craters and the shimmering plain of Lake Mono, and far away on the purple horizon the crests of some of the basin ranges. Over all is the deep blue summer sky of California, which is frequently without a cloud for many consecutive days.

Continuing our ascent, we climb scarps and cross irregular terraces until the way becomes too steep and rugged to ride; we dismount and throw the reins over our saddle-bows and, leaving our animals to follow their leader at will, continue the ascent on foot. Making a détour to the right and climbing a steep slope of débris that has been shot down from a lateral gorge, we attain a rude terrace on which is a lake filling a rock basin.

As some writers—especially those who are given to solving the mysteries of nature from their closets—have thought that lakes filling true rock basins are a rarity, and have even doubted whether they exist at all, we shall be interested in examining this result of glacial action, while we wait for our mule train to join us. The stream from above cascades over hundreds of feet of rock before reaching the lake; on either hand the overshadowing cliffs tower upward for a thousand feet; and we can walk along the lower border of the lake and find solid rock all the way across the cañon. There is no doubt, therefore, that the lake occupies a basin in solid rock. The ledge confining the waters rises in places almost perpendicularly to the height of over a hundred feet above the lake surface, and indicates by its rounded contour and polished and striated sides that the ice was once forced up from the basin now filled with water and flowed over the ledges and down the gorge. The sounding line tells us that the bottom of the basin is 51 feet below the lake surface. We thus have a rock basin of considerable depth, in the path of a glacier, the unmistakable markings of which descend into it on the upper side and emerge again at its lower margin. We will not pause to discuss the origin of this basin at present, but leave the reader to judge for himself whether it was actually excavated by flowing ice

or not, after he has read the section devoted to glacial phenomena, in which is recorded the evidence furnished by the Bloody Cañon and other similar localities in the Mono basin.

Proceeding, we find the way becoming steeper and more difficult; only the shadow of a trail remains; but our course is upward and we need no other guide. We make our way as best we can over loose rocks and steep ledges, and at length reach the divide which separates the drainage of the Mono basin from the water flowing to the Pacific. Instead of a sharp line of demarkation, however, we find the cañon bottom forming an irregular plain, broken by rocky bosses and occupied by lakelets and marshes, from which the waters flow both east and west. In reality, the deep, trough-like cañon we have ascended bends over the mountain crest and descends less steeply on the other side. This valley and other neighboring gorges of a similar character with which we shall become familiar before finishing the exploration we have begun, are remnants of an ancient drainage system which existed not only before the formation of the ancient glaciers that enlarged the valleys and modified their bottoms, but had its origin before the mountains themselves became a marked topographic feature. We are now so completely shut in by cliffs and mountain slopes limiting the view in every direction, that there is little evidence, besides the character of the vegetation, to indicate that we are over 10,000 feet above the sea.

On the divide there are a few cabins which mark the site of mining prospects. By the time these pages go to press, a thriving town may possibly be found here, so sudden are the changes that follow the discovery of rich ores.

Our trail, once more distinct, now follows the western drainage. As the descent is comparatively gentle, we remount and ride along in the shadow of scattered pines for three or four miles, having glimpses now and then of a forest-covered valley inclosed by towering cliffs of naked granite, until another stream, known as Dana Creek, which comes down the cañon between Mt. Dana and Mt. Gibbs, is reached. Here we establish a camp, turn our animals loose, and after requisite rest and refreshment start for the summit of Mt. Dana on foot. The climbing is not difficult; ladies have made the ascent, and W. D. Johnson, in occupying the summit for topographic purposes, carried his instruments there on muleback.

We toil up the southern slope, making at the same time a détour to the west, in order to find a more gradual ascent.[1] After about two hours' easy climbing, we gain the topmost crag and stand on the verge of the great precipice that forms the eastern face of the mountain and renders it a conspicuous feature when seen from Mono Valley. This precipice is also the left-hand wall of Glacier Cañon, a deep

[1] The peak may also be gained with ease by following up Dana Creek to the divide at its head and then ascending the crest at the head of Glacier Cañon.

gorge which follows the eastern base of the mountain and finally delivers its drainage to Leevining Creek, which conducts it to Lake Mono.

The object that first attracts the eye of the geologist from this point, claiming precedence even over the magnificent panorama of surrounding mountains and cañons and gem-like lakes, is a miniature glacier at the head of Glacier Cañon, and almost directly beneath his feet. This we call the Mt. Dana glacier. Crossing its surface are blue lines formed by deep crevasses; about its lower border are terminal moraines, forming crescent-shaped piles of débris; its surface is marked by concentric dirt bands; and resting on the ice near its lower margin are a number of bowlders on their way to join the terminal moraine at its foot. Below it is a lakelet of milky or opalescent water that finds outlet through a pile of morainal débris, which retains the matter in suspension, and supplies a number of lakelets in lower basins, each of which is as clear and blue as the sky above. This little ice body, scarcely half a mile long, has all the characteristics of the magnificent glaciers of Switzerland. Interest in it is heightened when we remember that it is one of the remnants of a vast glacial system which not very long ago was far more extensive than the present glaciers of Europe and filled all the cañons and higher valleys about us. We observe the records of ancient ice erosion on every side, and may see at a glance that glaciers formerly flowed away from the crest of the range through the various avenues that lead down the mountains. A vast névé or snow-field formerly crowned and enveloped the entire High Sierra and was the source of many glaciers like that which descended Bloody Cañon. The records of the ancient glaciers in that portion of the High Sierra which is included in the Mono basin will be considered a few pages farther on.

The summit on which we stand is 12,990 feet above the sea; it is only exceeded in altitude in the Mono basin by Mt. Lyell and Mt. Ritter, which rise with dazzling whiteness against the southern sky. These peaks are, respectively, 13,040 and 13,070 feet high. From the commanding summit of Mt. Dana nearly the entire Mono basin is in view, and we may study, as from a map, the principal features of our field of exploration.

We are standing on one of the highest points of the rim of a sharply defined hydrographic basin which has no outlet. The drainage from all parts tends toward the center and forms a lake from which the water escapes only by evaporation. We can trace nearly the entire boundary line of the basin, but, to complete its outline as indicated on the accompanying map, we should have to occupy many stations. Far below to the southeast lies Lake Mono, apparently silent and motionless. Should the wind chance to be strong in the valley, however, its surface will be streaked with long lines of foam,

and a white fringe will surround the plain of blue and render its outline unusually distinct. Beyond the lake the country seems low and lacking in relief, because of the elevation of our point of view. We can see far out over the rugged mountains of Nevada and note especially the angular outline and precipitous character of the White Mountains, the highest summit of which, McBride Peak, has a greater altitude than our present standpoint. To the right of Lake Mono are the Mono Craters. Although the higher of them have an altitude of nearly three thousand feet above the lake and are comparable with Vesuvius in grandeur, yet we can look down upon their summits, and the whole range is but a minor feature in the landscape. We notice that this line of cones does not terminate at the border of the basin, but other extinct volcanoes occur at intervals for a long distance to the southward. The more southern cones, however, are formed of basaltic rocks and are of a darker color than the highly acidic rhyolites forming the Mono Craters.

North and south from Mt. Dana the crest line of the Sierra is marked by peak after peak as far as the eye can reach. Turning south, we have in view a fine example, though not the very finest, of the rugged nature of the High Sierra. At the western base of Mt. Dana there is a deep, picturesque valley, dotted with lakes and traced with silvery streams. Like nearly all the depressions in the High Sierra, this valley owes its origin principally to erosion, and was formerly occupied by an immense glacier, or rather by a compound glacier—later in this paper called the Mt. Dana névé field—that flowed away in five directions. This valley differs from its neighbors in having its longer axis parallel with the trend of the range. The colors of the rocks are here rich and varied. Farther within the mountains the cold, gray monotony of the granites composing the greater part of the field of view replaces the variety of tints seen elsewhere. Across the valley to the nortwest rises Mt. Conness, bare, rugged, and grand. On its northern face a small glacier nestles in the shadows of bold cliffs. Beyond are many peaks equally striking in appearance and equally inviting to the mountaineer, but these are outside our district and can not receive attention at present. Twelve miles to the south, across a fragment of table land spared by the general erosion and known as Kuna Crest, are the spire-like peaks of Mts. McClure, Lyell, and Ritter. Throughout the year these summits are white with snow, and tempt the climber to scale their dizzy heights. With our field-glass we can see blue crevasses and dirt bands crossing the glaciers which cluster about them.

Returning from this vision of wild magnificence, the eye rests upon a scene humbler in its charms, but not less pleasing. Between the crags crowning the mountain and the highest of the contorted and deformed pines struggling for existence along the timber line, the trail leads over rocks and crags that at certain seasons are bright

with lichens and fringed with the purple and gold of the Alpine blossoms which flourish in every crevice and hollow where a little soil has accumulated. Sometimes the attention of the climber is attracted by what appears to be an Alpine glow on a mountain dome near the crest of the range, and he fancies that perhaps it is composed of some rock not yet recognized; but on reaching the summit he will be surprised to find himself in a field of lovely pink blossoms so thickly interwoven that it is impossible to tread the ground without crushing many of them at every step. In these elevated regions May day is a festival of late summer, but it brings with it a multitude of charms that are unknown to dwellers in the world below.

We desire to press on, like all explorers, and to thread the labyrinth of cañons and climb some of the lofty peaks filling all the region in view, but even the fireside traveler has to limit his journeys and turn homeward. The traveler who may actually follow the route here indicated will find that he has only entered the borders of a wonderland when he gains the summit of Mt. Dana. Beyond not only lie deep valleys, unknown except to the shepherds who pasture their flocks there in the summer, and lofty mountains unscaled even by the hunter, but almost in sight are the far famed Yosemite and groves of giant sequoias. On descending from Mt. Dana the traveler will find a well constructed wagon road near the west base of the mountain, which leads southward into the valley of the Tuolumne and on over the mountains west of the Yosemite, which will enable one to journey with ease through a mountain range that is among the most attractive and most instructive in the world.

Leaving the High Sierra and the regions beyond for future examination, let us see what geological lessons may be learned in the restricted area we have chosen for study. We may call our fancied ride a preliminary reconnaissance, and from it plan our future lines of research.

We have seen that the present lake in Mono Valley is in many ways an exception to the water bodies with which we are most familiar, and at some former time was far more extensive than at present. The lacustral history of the valley will therefore offer many facts of interest.

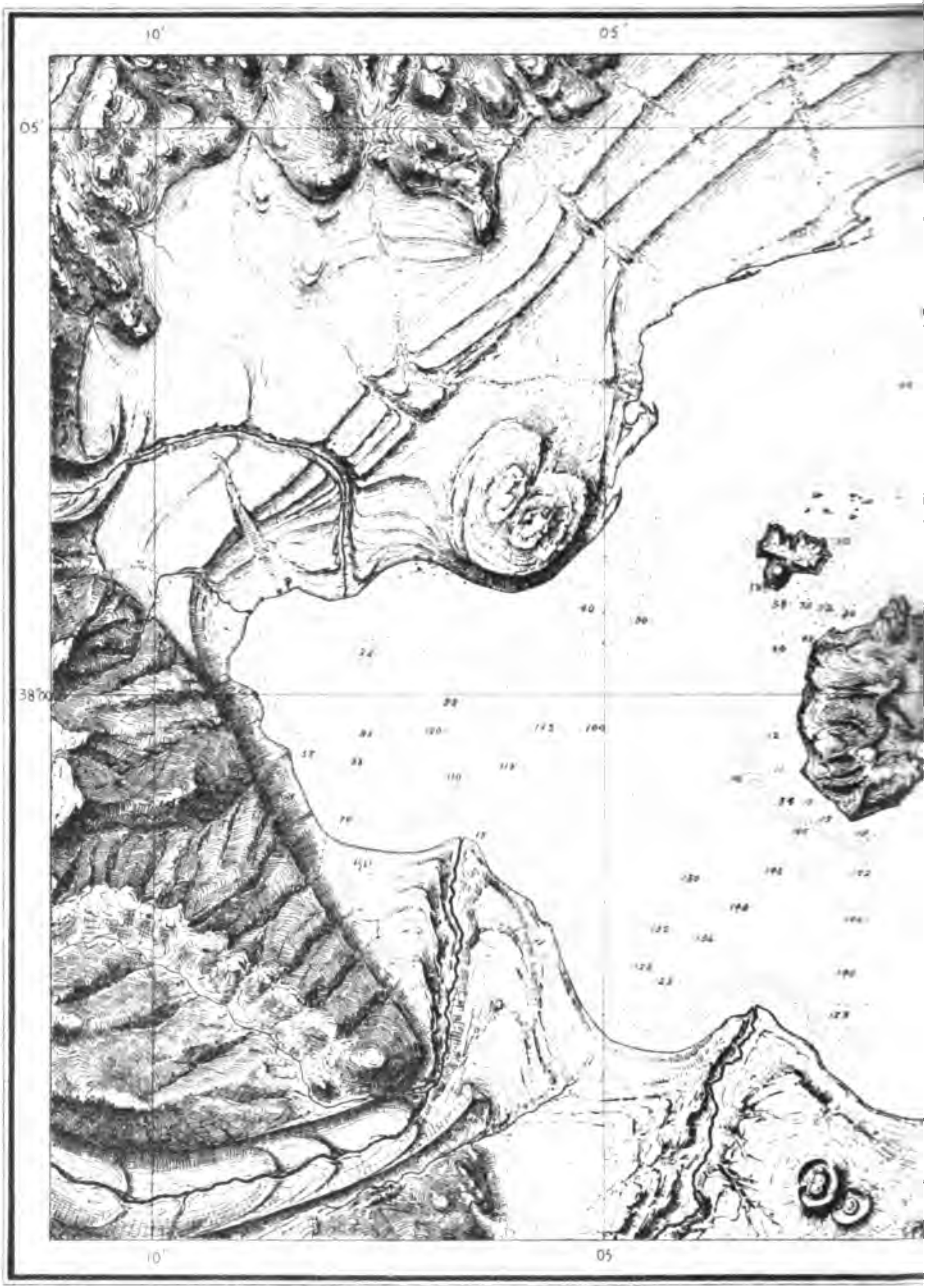
The glaciers occupying a few of the more sheltered cirques about the loftiest peaks of the High Sierra may be considered remnants of the magnificent rivers of ice that formerly descended from the same fountains. The existing glaciers and the evidences of past glaciation are of great geological interest and record the glacial history of our field of study.

Hot springs boiling up in various parts of the basin indicate that the volcanic energy which extruded the material forming the Mono Craters is perhaps not entirely dissipated, while the freshness of many of the cones and coulées of lava is proof that the volcanic

forces which built them were in full activity within very recent times. The volcanic history of the field of study will therefore demand a share of attention.

After tracing back the more instructive phenomena of the region in the manner indicated in the three preceding paragraphs, we shall have reviewed the lacustral, glacial, and volcanic records; these, when combined, furnish the most important elements in the Quaternary history of Mono Valley.

U.S. GEOLOGICAL SURVEY



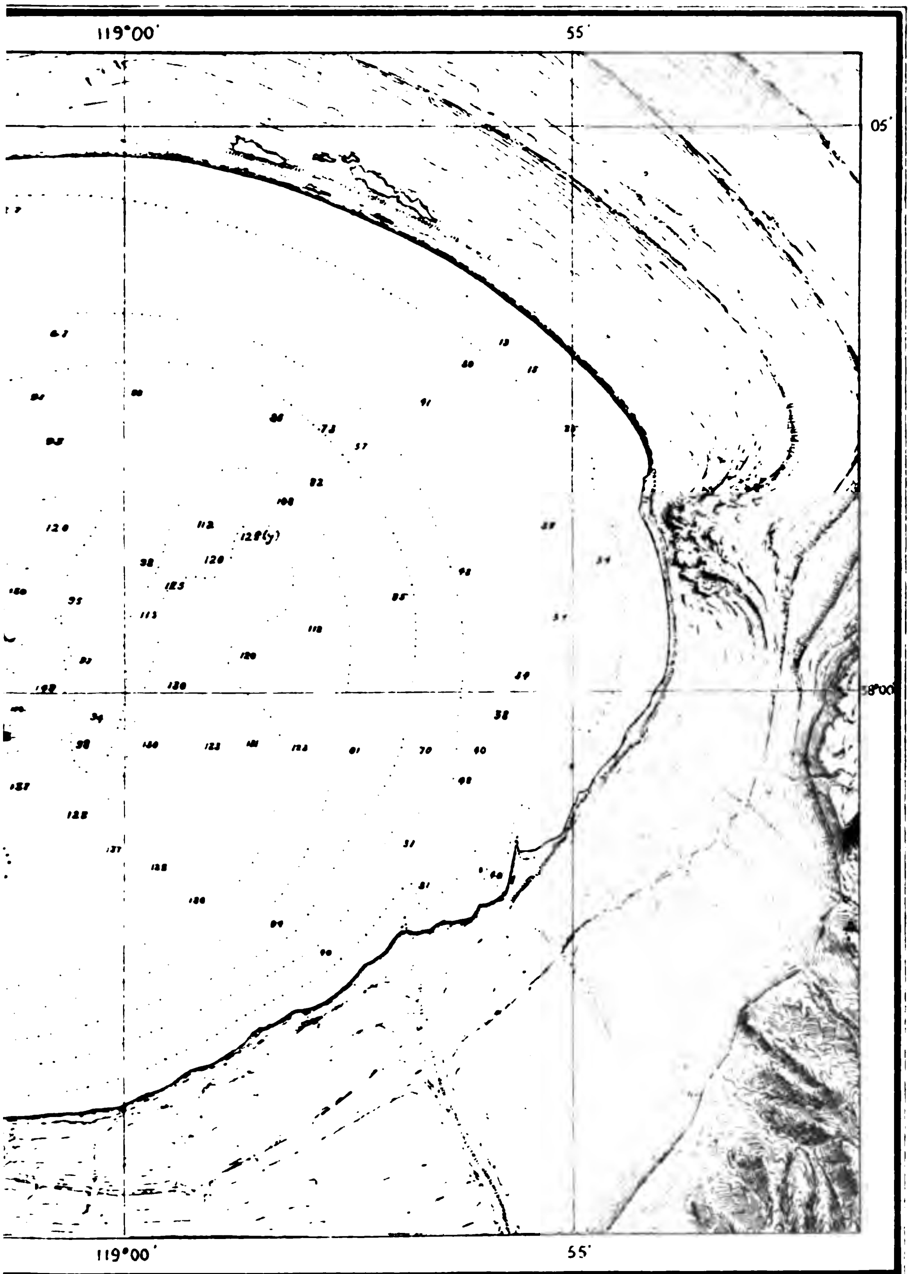
W. D. Johnson, Topographer

SCALE

1 0 1 2 3 4

LAKE M

Soundings in feet. Sublacustral contours



I. C. Russell Geologist.

25,000.

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approximate Contour interval 25 feet

LACUSTRAL HISTORY.

THE PRESENT LAKE.

Lake Mono is rudely circular in outline. Its north and south axis measures 10 miles and its east and west axis 14 miles. Including islands, its area is 87 square miles. The actual water surface in the summer of 1883, when the accompanying map (Pl. XIX) was made, was between 84 and 85 square miles. The soundings shown on the map are from actual measurements and furnish the basis for the sub-lacustral contour lines represented. The vertical interval between the contours is 25 feet. The deepest part of the lake is near the southern border of the terrace surrounding Paoha Island, where our sounding gave 152 feet of water. The average depth of the lake is between 61 and 62 feet. The entire bottom is of soft, black mud, excepting to the south of the larger islands, where a tenacious blue clay is found over a considerable area. About the shore, a narrow band of volcanic sand and gravel, derived from the Mono Craters and from Black Point, records the transporting power of waves and currents. The most remarkable features of the lake are the absence of an outlet and the strongly alkaline condition of its water.

SOURCES OF WATER SUPPLY.

The lake derives the principal portion of its water supply from the creeks that descend the eastern slope of the Sierra and empty into it from the south and west. Supplementing the surface drainage are a number of springs, some of which are of considerable size.

Streams.—The creeks tributary to Lake Mono are of clear pellucid water, and flow through channels excavated for the most part in granite and metamorphosed sediments, but near their mouths they have eroded small gorges through lacustral marls and volcanic lapilli deposited during previous high water stages of the lake. No chemical analyses of these waters have been made, but they have, without question, the normal purity of mountain streams. We may be sure, however, that like other streams they hold a small percentage of mineral matter in solution, which is left when evaporation takes place.

Springs.—None of the springs of the basin are highly charged with mineral matter, but, on the contrary, some of the more copious are remarkable for their purity. The locations of the springs are indicated on the accompanying map (Pl. XVII), which renders it

unnecessary to enumerate them in detail. The smaller ones, so situated as probably to be of local origin, may be classed as "hill-side springs," in distinction from those rising from a great depth through fissures and hence termed "fissure springs."

With the exception of a very small spring on the road between the town of Aurora and the valley of the same name all springs of the basin are either in the bottom of the lake or quite near its shores, and they occur in greatest abundance near the base of the mountains. Only three of those that rise on the land have a temperature noticeably above the normal. The character of most of those rising in the bottom of the lake is uncertain. In some instances they reveal their presence in cold weather by the vapor to be seen on the lake surface above them, and are thus known to be thermal.

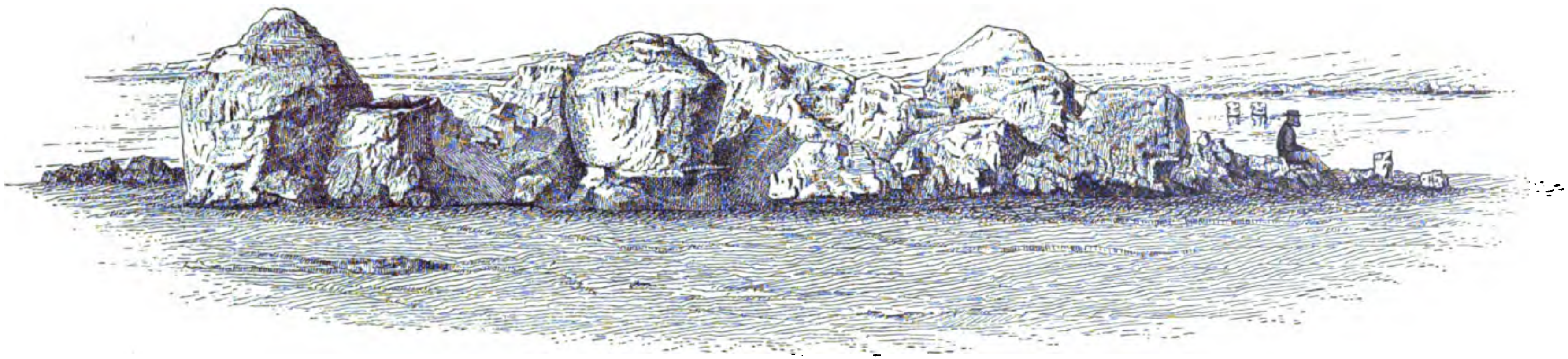
The most copious of the thermal springs is situated on the northeast shore of the lake and is known as Warm Spring. Its discharge is, by estimate, about 10 gallons a minute, and its temperature is between 80° and 90° F. A sample of its water has been analyzed by T. M. Chatard, who reports its composition as follows:

Analysis of water of Warm Spring.

Constituents.	Grams in a liter.	Per cent. in total solids.	Probable combination.	Grams in a liter.
Silica (SiO_2)	0.1220	5.89	Alumina (Al_2O_3)	0.0018
Alumina (Al_2O_3)	0.0018	0.09	Calcium carbonate ($CaCO_3$)	0.1475
Calcium (Ca)	0.0589	2.84	Magnesium carbonate ($MgCO_3$)	0.2114
Magnesium (Mg)	0.0604	2.92	Potassium chloride (KCl)	0.1203
Potassium (K)	0.0630	3.05	Sodium chloride (NaCl)	0.2799
Sodium (Na)	0.6116	29.56	Sodium sulphate (Na_2SO_4)	0.4631
Sulphuric acid (SO_4)	0.3131	15.13	Sodium silicate (Na_2Si_3)	0.2480
Chlorine (Cl)	0.2272	10.98	Sodium carbonate (Na_2Co_3)	0.5972
Oxygen (O)* a	0.0325	1.57		
	1.4905	72.03	Total (99.24 per cent. accounted for)	2.0692
Carbonic acid (CO_2) by difference	0.5787	27.97		
Total	2.0692	100.00		

* a Added to SiO_2, to form SiO_2 of $Na_2\ SiO_3$.

At Hot Spring Cove, on the eastern side of Paoha Island, a thermal spring of considerable size comes to the surface just within the margin of the lake as it stood in September, 1883. The temperature of this spring is about 110° F. Although not of great volume its position is rendered conspicuous, especially in winter, by the column of steam rising from it. On the steep slope of volcanic rock immediately above this spring, vapors with a temperature of 150° F. escape from numerous holes and crevices of the nature of fumaroles. On cold days the vapor ascending from these vents can sometimes be seen many miles. At times the position of the vents is indicated only by a thin wreath of vapor, but occasionally a column of steam



TUFA DEPOSITED FROM SPRINGS NEAR BLACK POINT.

From a photograph

hundreds of feet high may be observed to rush upward for a few minutes, indicating, apparently, that the orifices sometimes become obstructed and are cleared by an eruption. On the west shore of Hot Spring Cove another thermal spring, called Petroleum Spring on account of its odor, rises at a point a few feet above the lake margin and discharges a few gallons of water a minute. Its temperature is 96° F. A partial analysis of its water shows that it contains 0.8775 grams of solid matter to the liter, consisting of carbonates, chlorides, and silicates, of calcium, magnesium, sodium, and potassium.

Near the base of the hills on the northwest side of Lake Mono and about three miles from the water's edge, there are a number of copious springs situated along a line of recent faulting. These discharge water of normal temperature, which to the taste does not reveal the presence of mineral matter in solution. One of these is the largest spring in the basin, excepting, perhaps, some of those rising within the border of the lake, and discharges sufficient water to irrigate several acres of land.

At the western extremity of the lake are a number of springs, some of which are sublacustral. Two of special interest rise at the bases of tufa crags at a distance of twenty or thirty yards from the lake. That they have been flowing for a great length of time seems evident from the fact that the tufa about them was deposited from waters issuing from the same orifices when the lake stood far above its present level. They are copious, each delivering perhaps twenty gallons of water a minute, but it was not practicable to measure their volume. They are clear and cool and evidently of exceptional purity. At the present time they are not depositing mineral matter. They are subaerial, instead of sublacustral, and it is impossible to determine whether their composition at present differs materially from what it was when the calcareous deposits about them were formed. The appearance of the most typical of the calcareous deposits in this portion of the basin, and one at the base of which a copious spring now issues, is shown on Pl. XX.

The positions of the springs rising in the lake near Black Point are indicated in calm weather by the eddies they produce on the lake surface. On rowing over these submerged springs we find that some of them rise from the tops of tufa crags which are covered by ten or twelve feet of water. These crags are of the same character as those standing on the shore, illustrated on Pl. XX, and were formed by the deposition of calcium carbonate from the incoming waters. The submerged towers from which these springs issue are in some instances eight or ten feet in diameter and have a height of twenty or thirty feet. They are clustered in groups in the same manner as the tufa towers and castle-like masses mentioned above, which have been left exposed by the receding of the waters of the lake. Unlike the

deposits that have been exposed to the atmosphere, their forms are unbroken, showing that the lake has never evaporated sufficiently to bring them above the surface or at least to expose them for a long period. The upward rush of fresh water from the orifices in the summits of these sublacustral towers, through the denser waters of the lake, is in some instances sufficiently strong to deflect a boat when allowed to float over them. When the lake is placid, a low mound, forty or fifty feet in diameter, may be seen where the incoming waters rise to the surface.[1]

Other tufa domes, similar to those we have mentioned, rise above the surface of the lake near the shore and add a most interesting and novel feature to the scenery. A group of these domes, seen from the shore near Black Point, looking toward Mt. Warren, is represented on Pl. XXI. They rise in water that is ten or twelve feet deep, to a height of about twelve feet above the lake surface. Many of them are vase-shaped, as shown in the illustration, being smallest at the water's surface and nearly circular in outline.[2] The more symmetrical ones appear not unlike huge specimens of the sponge known as Neptune's Cup. The tops of several are hollowed out so as to form basins, and in a few instances these depressions are filled with clear, fresh water that rises through the porous and tubular tufa composing the submerged shaft of the structure. These are typical specimens of sublacustral spring deposits, which have been left partially exposed by a recession of the lake waters, but are still points of discharge for the springs that built them.

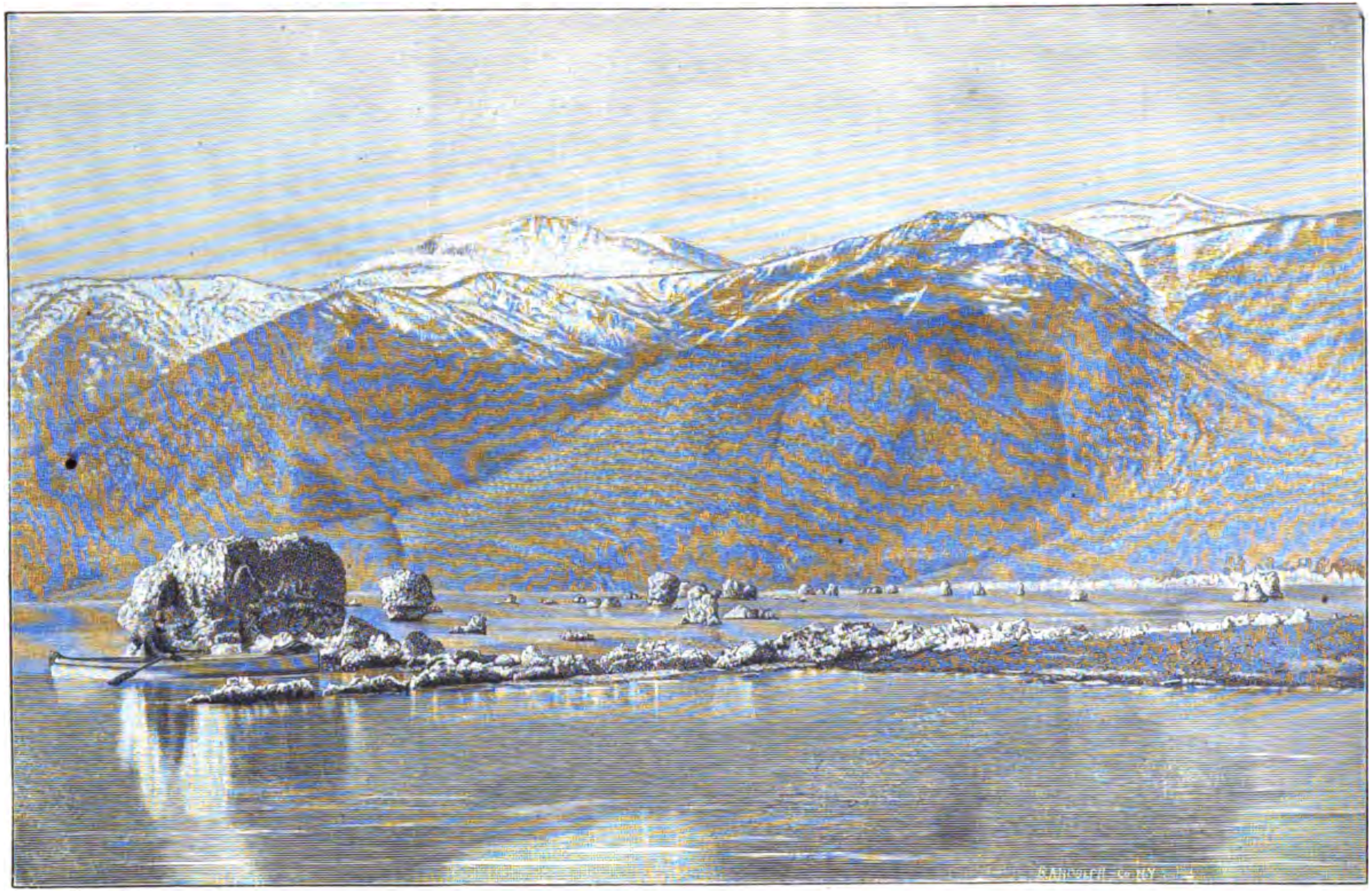
The water of one of these natural fountains, rising in a lake whose water is utterly undrinkable, is of exceptional purity, as shown by T. M. Chatard, who reports its composition as follows:

Analysis of water from a spring in Lake Mono.

Constituents.	Gram in a liter.	Per cent. in total solids.	Probable combination.	Gram in a liter.
Silica (SiO_2)	0.0178	6.10	Silica (SiO_2)	0.0178
Calcium (Ca)	0.0414	14.19	Calcium carbonate ($CaCO_3$)	0.1035
Magnesium (Mg)	0.0044	1.51	Magnesium carbonate ($MgCO_3$)	0.0154
Potassium (K)	0.0088	3.02	Potassium chloride (KCl)	0.0169
Sodium (Na)	0.0513	17.58	Sodium chloride (NaCl)	0.0104
Sulphuric acid (SO_4)	0.0546	18.71	Sodium sulphate (Na_2SO_4)	0.0799
Chlorine (Cl)	0.0144	4.93	Sodium carbonate (Na_2CO_3)	0.0506
	0.1927	66.04	Total (100.91 accounted for).	0.2945
Carbonic acid (CO_2) by difference	0.0991	33.96		
Total	0.2918	100.00		

[1] A description of these springs is given in Report of the U. S. Geological Exploration of the Fortieth Parallel, vol. 1, 1878, p. 513.

[2] The contraction of the towers at the present water surface may be due to the dash of waves or perhaps to solution by the water of the lake of the calcium carbonate of which they are composed.



TUFA TOWERS IN LAKE MONO.
From a photograph.

This spring fills a bowl three or four feet in diameter, in the top of a tufa dome which rises about three feet above the lake surface and overflows, fountain-like, into the surrounding alkaline waters. The interior of the basin, and portions of its exterior, are coated with white, calcareous tufa, which is still being precipitated from the outflowing waters.

The only other instance known to the writer where fresh water springs have built up islands in a saline lake is in Lake Tezcoco, Mexico. These springs are described by Mayne Reid[1] as follows:

Another singular fact in regard to Tezcoco is that at certain places far apart, and far away from its shores, are fresh water springs which spurt up in the midst of little islets they have themselves made. These diminutive *eyots*, termed by the Lake Indians *tlalteles*, or "earth-mounds," are covered with a scanty salitrose vegetation. Though not observable from any great distance, they are known to those who navigate the lake; and the boatmen often bring up alongside of them to drink, or fill their *xuages* (calabash canteens) from the springs.

Many small springs also rise in the western portion of Lake Mono, especially about the bases of the tufa crags that stand in the water, their presence being indicated by oily lines, produced as the fresh water mingles with the denser solution of the lake, and by bubbles of gas, probably carbon dioxide, which occasionally rise to the surface.[2]

The springs of the Mono basin are mainly in proximity to the great displacement determining the eastern face of the Sierra Nevada, and belong, for the most part, to a belt of fissure springs, extending for hundreds of miles along the eastern base of the mountains. Northward of Mono Valley this belt is marked by extensive springs of heated water near Bridgeport,[3] the situation of which is indicated on the accompanying map. Many others belonging to the same belt occur at intervals all the way northward to beyond the Nevada-Oregon boundary. South of Mono Valley similar springs are to be seen about the headwaters of Owen's River; of these Casa del Diablo is one of the best examples. This line of thermal springs is known to extend southward beyond the end of the Sierra Nevada. Many of the springs in this great belt, especially those having a high temperature, are fissure springs, and rise from great depths

[1] Land and Water, London, vol. 21, 1876, p. 307.

[2] The oily lines formed by these springs as they rise through the waters of the lake have led many persons to suppose that they were in reality due to oil exuding from the lake bottom. This is not the case; and any one may assure himself that such lines are produced by pure water rising in a denser solution by introducing fresh water through a tube at the bottom of a glass vessel filled with water from the lake and observing the manner in which they mingle.

[3] These springs were examined by Willard D. Johnson, who reports them to be the most copious of any in the region embraced on the accompanying map. The peculiar aqueduct-like branches of tufa frequently seen in ancient spring deposits, which have been built out in irregular radial lines from a central, crater-like bowl of the same material, may here be observed in process of formation. A locality of former spring action, three miles southeast of Bridgeport Springs, is also represented on the map. A recent fault through these two localities is suspected, but has not been traced with certainty in the field.

through the fractures that occur mostly along lines of displacement. In many instances, as recorded in a former paper,[1] the association of hot springs with lines of post-Quaternary displacement indicates that the hot springs of the Great Basin have an intimate connection with recent orographic movements and perhaps owe their high temperature to heat produced by the friction of the rocks along fault planes.

As may be seen from this brief description of the streams and springs of the Mono basin, the water supply of Lake Mono is in no way remarkable, and does not differ in any essential particular from that of many of the basins of the Far West. There being no other source of supply for the salts contained in the lake, we must conclude that its density has resulted from the concentration of ordinary surface waters, mingled with a comparatively small percentage of spring water, which, however, is in no instance rich in saline matter. The older rocks of the Mono basin are largely volcanic. The Mono Craters and other modern volcanoes have contributed vast quantities of lapilli and pumiceous dust to the filling of the basin. These products of volcanic activity are more soluble than the granites and metamorphosed sediments in which streams rising in the Sierra Nevada have excavated their channels, and probably exert a controlling influence on the chemistry of the lake waters. From this circumstance alone we should expect that the lake would be characterized by the presence of soda and potash salts, as these are the most soluble ingredients of the lavas. This hypothesis, I think, is sustained by the chemical studies which follow.

CHEMICAL COMPOSITION.

For the purpose of ascertaining the chemical composition of Lake Mono, two samples of its water were collected at a point 1.7 miles northeast of the largest island (indicated at *y* on Pl. XIX). One of the samples was taken one foot below the surface and the other, by means of a Sigsbee's deep-sea sounding cup, at a depth of 100 feet. There were no indications that sublacustral springs enter the lake near where the water for analysis was collected, and we have every reason for believing that the composition reported below represents the true chemical character of the lake, as nearly as could be determined from an examination of an equal number of samples.

All the creeks tributary to Lake Mono enter it along its southern and western border. For this reason the composition of the lake at various points might be expected to vary; but the character of the water, as observed while making soundings, indicates, when not in the immediate proximity of streams or springs, that the variation is slight. The water obtained one foot below the surface was examined quantitatively, but the other sample was only partially analyzed. The surface sample gave 51.85 grams in a liter of solids in solution,

[1] Third Ann. Rept. U. S. Geol. Survey, 1881–'82, p. 232.

while the sample from the bottom gave 52.85 grams in the same amount. Qualitative examination showed that the constituents of the bottom sample were the same as in the surface water, the analysis of which (made by T. M. Chatard) is here inserted.

Analysis of the water of Lake Mono.

Constituents.	Grams in a liter.	Per cent. in total solids.	Probable combination.	Grams in a liter.
Silica (SiO_2)	0.2800	0.54	Silica (SiO_2)	0.2800
Calcium (Ca)	0.2900	0.55	Calcium carbonate ($CaCO_3$)	0.6800
Magnesium (Mg)	0.1300	0.28	Magnesium carbonate ($MgCO_3$)	0.3600
Potassium (K)	1.1600	2.23	Potassium chloride (KCl)	2.2800
Sodium (Na)	18.9100	36.46	Sodium chloride (NaCl)	18.2200
Sulphuric acid (SO_4)	6.8100	13.11	Sodium sulphate (Na_2SO_4)	10.0700
Chlorine (Cl)	12.1300	23.39	Sodium borate ($Na_4B_4O_7$)	0.2000
Boracic acid (B_4O_7)	0.1600	0.34	Sodium carbonate (Na_2CO_3)	19.4900
	39.8700		Total (99.60 per cent. accounted for)	51.5800
Carbonic acid (CO_3) by difference	11.9800	23.10		
Total	51.8500	100.00		

The characteristic chemical feature of the water, as shown by the analysis, is the high percentage of sodium carbonate in comparison with the amount of sodium chloride present.[1] The concentra-

[1] In connection with some experiments on fractional crystallization, Mr. Chatard had occasion, after this paper was written, to make a more careful analysis of the water of Lake Mono than the one given above. In this investigation a mixture of the top and bottom samples already mentioned was used. The results of this investigation are here presented and may be taken as approaching more nearly the average composition of the lake than the previous analysis.

Analysis of the water of Lake Mono.

Constituents.	Grams in a liter.	Per cent. in total solids.	Probable combination.	Grams in a liter.
Silica (SiO_2)	0.0700	0.120	Silica (SiO_2)	0.0700
Calcium (Ca)	0.0200	0.037	Calcium bicarbonate ($CaH_2C_2O_6$)	0.0810
Magnesium (Mg)	0.0551	0.103	Magnesium bicarbonate ($MgH_2C_2O_6$)	0.3349
Potassium (K)	0.9614	1.795	Potassium chloride (KCl)	1.8342
Sodium (Na)	19.6853	36.810	Sodium chloride (NaCl)	18.5068
Alumina (Al_2O_3), Ferric oxide (Fe_2O_3)	0.0030	0.005	Sodium sulphate (Na_2SO_4)	9.8690
Sulphuric acid (SO_4)	6.6720	12.480	Sodium carbonate (Na_2CO_3)	18.6720
Chlorine (Cl)	12.1036	22.630	Sodium bicarbonate ($NaHCO_3$)	3.9015
Boracic acid (B_4O_7)[a]	0.1600	0.300	Sodium borate ($Na_4B_4O_7$)	0.2000
Carbonic acid (CO_3)	13.6908	25.610	Alumina (Al_2O_3)	0.0030
Water, in bicarbonates (H_2O)	0.4683	0.100		
Total	53.4729	100.000	Total	53.4729

[a] Taken from previous analysis.

The water having deposited flakes of silica, it was filtered before analysis. Specific gravity, 1.0456 at 15.5° C. Published in Am. Jour. Sci., 3d Series, vol. 36, 1888, p. 149.

tion of surface waters by evaporation, as observed in many parts of the world, produces, in general, brines of two characters; in one class, sodium chloride predominates over all other salts, as is shown on a grand scale in the waters of the ocean, as well as in many inclosed lakes; in the other class, alkaline carbonates are abundant, and may equal or exceed the amount of sodium chlorides present. From the studies of various observers it seems evident that the two classes of brines I have indicated, when forming lakes, may be correlated with differences in the geologic character of the hydrographic basins in which they are situated. As a rule, we may expect that the inclosed lakes of a region underlain by stratified sedimentary rock will be richest in sodium chloride, as is illustrated in the case of Great Salt Lake, while water bodies of similar origin in volcanic regions will be characterized by high percentages of sodium and potassium in combination with carbonic and sulphuric acids.

For the purpose of comparing the composition of the lake we are studying with analogous water-bodies, Table A of analyses showing the composition of the better-known inclosed lakes in the world is introduced. It will be seen that many of them exceed Lake Mono in the total of solids in solution, but if we make the most probable combination of the acids and bases given in the table, so as to show the salts contained in the various lakes, we shall find that Lake Mono is richer in sodium carbonate than any other on the list, with the exception of the Soda Lakes near Ragtown, Nev., and Owen's Lake, Cal.

The larger of the Soda Lakes, near Ragtown, the analysis of which is given in the table, occupies the bottom of a volcanic crater composed principally of lapilli, and is supplied entirely by springs. It is, therefore, quite different in character from the others on the list, and affords few points of comparison with the lakes we are now principally interested in.

Owen's Lake, in many ways the homologue of Mono, is situated about one hundred and twelve miles farther south. Each of these lakes has about the same relation to the Sierra Nevada, from which they derive their principal water supply, and they seem to have very similar chemical histories. Owen's Lake, like Lake Mono, was at one time much larger than now, and owes its present density to concentration. Its composition, as reported by Oscar Loew, who visited it in 1876,[1] is given in the following table, in which the most probable combination of acids and bases is indicated. We have reduced the analysis to grams per liter, for the sake of ready comparison with the analysis of the water of Lake Mono given above.

[1] U. S. Geographical Surveys West of the 100th Meridian; Annual Report, 1876, p. 190. A later analysis of the water of this lake by T. M. Chatard is given in Table A.

Analysis of the water of Owen's Lake, Cal.

Constituents.	Grams in a liter.
Potassium sulphate (K_2SO_4)	6.4487
Sodium sulphate (Na_2SO_4)	9.2907
Sodium carbonate (Na_2CO_3)	24.4080
Sodium chloride (NaCl)	23.2830
Silica (SiO_2)	0.1721
Lithium (Li)	Trace.
Calcium (Ca)	Trace.
Magnesium (Mg)	Trace.
Aluminium (Al)	Trace.
Boracic acid (B_4O_7)	Trace.
Phosphoric acid (P_2O_5)	Trace.
Nitric acid (HNO_3)	Trace.
Organic matter	Trace.
Total	63.6025

Specific gravity, 1.051.

Mr. Loew computes that the lake contains 22,000,000 tons of sodium carbonate and 5,000,000 tons of potassium sulphate. The only lake besides Owen's of known composition on this continent that can be compared with Lake Mono in reference to the chemical and economic importance of its brine is Abert Lake, Oregon, the composition of which is given in Table A. Summer Lake, Oregon, is similar to Abert Lake in all its general features. It is a dense alkaline solution, but no analysis of its waters is known.

The economic importance of the desert lakes of the Great Basin lies in the practically unlimited quantities of sodium salts they are capable of yielding. Up to the present time Great Salt Lake, Owen's Lake, and the Soda Lakes near Ragtown are the only ones that have been utilized.

From the area of Lake Mono (85.5 square miles), its average depth (61.5 feet), and chemical composition, one is enabled to make some interesting calculations concerning the amounts of the various salts it contains. The volume of the lake is 5,365,816,000 cubic yards, or .984 cubic mile; equivalent to 1,083,755,500,000 gallons of 231 cubic inches each. The weight of the lake, each liter containing 1,051.85 grams, is 4,725,557,000 tons of 2,000 pounds each.

The total weight of salts in the lake, together with the weight and percentage of each salt shown in the column of probable combination in the analysis on page 293, is given in the following table:

Salts in the water of Lake Mono.

Constituents.	Grams in a liter.	Tons in lake.	Percentage of total weight of lake.
Silica (SiO_2)	0.28	1,323,200	0.028
Calcium carbonate ($CaCO_3$)	0.68	3,213,400	0.068
Magnesium carbonate ($MgCO_3$)	0.36	1,701,200	0.036
Potassium chloride (KCl)	2.23	10,538,000	0.222
Sodium chloride (NaCl)	18.22	86,099,600	1.822
Sodium sulphate (Na_2SO_4)	10.07	47,586,400	1.007
Sodium borate ($Na_4B_4O_7$)	0.20	945,100	0.020
Sodium carbonate (Na_2CO_3)	19.49	92,101,100	1.949
Unaccounted for	0.32	1,512,200	0.032
Total	51.85	245,020,200	5.185

Should labor and transportation become cheaper in the Far West, or should the demand for sodium carbonate increase, the waters of Lake Mono will afford the basis for an extensive industry. The desert tracts bordering the lake on the north offer advantageous sites for solar evaporation, while the forests of the Sierra will afford fuel for artificial evaporation should this be found more economical.

The lakes we have mentioned on the last few pages afford only a portion of the salts and alkalies available for economic purposes in the Great Basin. There are also desiccated lake beds in which the more soluble salts derived from the surrounding rocks have been concentrated for ages, and now form fields of common salt that are in some cases many square miles in area and hold brine in all stages of saturation beneath their surfaces. Besides sodium chloride, some of these dry lake beds contain boracic acid in combination with various bases (from which borax is manufactured), together with sodium carbonate and vast quantities of sodium sulphate. The salt and alkali deposits of the Great Basin constitute important elements of its natural wealth, but up to the present time no systematic attempt has been made to develop them.

CHEMICAL DEPOSITS.

The geological interest of the various calcareous tufas precipitated from the waters of the Quaternary lakes of the Great Basin led to the hope that the present inclosed lakes of the region, which are more or less concentrated chemical solutions, would reveal the manner in which these deposits were formed. Information is especially desired in reference to the mode of formation of the crystalline variety of tufa known as thinolite, which up to the present time has proved

an enigma to both geologists and mineralogists. Thinolite has thus far been found in this country only in the basin of Lake Lahontan and about Lake Mono, excepting some crystals from Oregon obtained by J. D. Dana[1] during the Wilkes expedition, the mode of occurrence of which is certainly different from that of the Nevada and California localities. None of the existing lakes of the Lahontan Basin hold more than a fraction of 1 per cent. of mineral matter in solution (not including the soda lakes near Ragtown, which are of an exceptional nature) and none are now depositing thinolite; but it was thought that in the dense waters of Lake Mono the crystallization of this mineral might be found in progress. The results of our observations, however, have been negative so far as the discovery of the origin of thinolite is concerned.

The sands and pumiceous lapilli forming the immediate border of Lake Mono are often cemented by calcium carbonate into a semi-compact sandstone or breccia, but beyond this no chemical precipitation is known to be in progress. The comparatively small percentage of calcium in the waters of the lake shows that this element must be deposited as fast as it is delivered by the inflowing streams and springs. It appears to be precipitated in an amorphous condition, forming a cement for the sand and lapilli along the lake shore or becoming mingled with the mud of the lake bottom. It does not form a sheet of tufa at the bottom of the lake nor coat the rocks now washed by the waves.

Our observations failed to show that any of the springs now rising in the lake are forming calcareous deposits. The tops of the submerged domes from which spring water is now issuing have the same appearance as the summits of the similar ones rising above the surface of the lake or standing on the land which are no longer points of discharge. The only spring observed to be forming a precipitate was the one rising in the top of a tufa crag standing in the lake near Black Point, a description of which has been given on page 290. The deposit from this spring consists of calcium carbonate, which is precipitated before the spring water reaches the lake water; it is therefore of the nature of an ordinary subaerial spring deposit.

Crystals of gaylussite are said to have been found in Lake Mono, but none were observed by the writer. This apparent discrepancy may be due to the fact that the lake is now several feet higher than formerly, and is consequently a more dilute solution. It may be that the critical point as regards the crystallization of gaylussite lies between the former and the present conditions of the lake and that the crystals previously formed are now dissolved.

The tufa crags so situated as to be washed by the waves, as well as the cave-like recesses in the cliffs rising from the water's edge, especially along the shores of Paoha Island, are frequently whitened

[1] Geology of the U. S. Exploring Expedition, p. 656, Washington, D. C., 1849.

by an efflorescence consisting principally of sodium carbonate and sodium sulphate. The formation of this efflorescence is due to the absorption of water of the lake by the porous rocks and its passage to the surface through the action of capillary attraction; it is then evaporated, leaving the salts it formerly held in solution as a superficial coating. Frequently the basins in the summits of some of the vase-like tufa crags near Black Point are partially filled with white, flocculent salts of this description.

FLUCTUATIONS OF LEVEL.

Lake Mono, like all inclosed water bodies, is subject to changes of level, dependent on alternations of seasons and on secular climatic oscillations. There are no definite records of the recent variations the lake has undergone, but persons who have been familiar with it for many years have noticed that it is subject to considerable fluctuation. During the past twenty or twenty-five years it is thought by some to have risen as much as fifteen or twenty feet. The road along the south shore of the lake between Lundy and Leevining Cañons is now crowded close to the base of the mountain, and would be submerged in places by a rise of a foot or two in the waters of the lake. I have been told by residents in the valley that about twenty years ago there was a comparatively broad stretch of beach along this portion of the shore, between the lake margin and the abrupt base of the mountain. It is also stated that on the northern side of the smaller of the two main islands in the center of the lake a cabin was built in 1861, which is now wholly submerged. This would indicate that a recent rise of twenty or twenty-five feet in the lake surface has taken place or else the island has undergone subsidence to that extent. These statements are of little more than qualitative value, it is true, but they indicate with considerable certainty that the lake is higher now than when first seen by the settlers of the region. This conclusion is also sustained by the occurrence of dead stumps of trees and sage brush in the margin of the water at a distance of two or three hundred feet from the land. These prove that a relative change in the height of the land and water of at least five or six feet has taken place within a comparatively short time.

In an account of Lake Mono by Joseph LeConte,[1] who visited it in 1870 and again in 1872, it is stated that fences, corrals, and trails were then submerged several feet, and that dead bushes standing in the lake recorded a rise of five feet. Professor LeConte's observations led him to conclude that the lake at the time of his visit was rising and had been rising for ten or fifteen years. A recent rise was also observed by Clarence King, who ascribes it to climatic change and correlates it with similar fluctuations in other inclosed lakes of the Arid Region.[2]

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[1] Am. Jour. Sci., 3d series, vol. 18, 1879, pp. 35-44.
[2] U. S. Geological Exploration of the 40th Parallel, vol. 1, p. 525.

The unweathered domes of the sublacustral tufa crags near Black Point, mentioned on page 289, bear witness that the lake surface in that part of the basin has not stood at a level more than twelve or fifteen feet below the present water surface since the deposition of the tufa took place. This, together with the evidences of recent terrestrial disturbances to be seen in the bottom of the lake near the south shore at Paoha Island and on Black Point, as described on page 290, indicates that the apparent changes in the level of the lake are due in part at least to orographic movement, and not wholly, as has been supposed, to climatic change.

To aid in determining future fluctuations of level, a bench mark was made by W. D. Johnson on an outlying crag[1] on the southwest shore of Negit Island, the position of which is indicated by the letter *x* on the accompanying map (Pl. XIX). This, together with the topography of the lake shores and soundings recorded upon the map, will enable the future inquirer to determine with accuracy any changes in the level of the lake that may take place. As Mono Valley is in a region of recent orographic disturbance, careful attention will be required to determine whether future changes in the relative height of land and lake surface are due to variations of lake level or result, as suggested in the last paragraph, from upheaval and subsidence. Movements along the fault lines that occur in the basin are to be expected and should be looked for with especial care.

The fluctuations of the lake during the past few years naturally lead to the consideration of its changes in prehistoric times.

THE QUATERNARY LAKE.

The fact that Lake Mono was formerly much larger than at present has already been recognized by J. D. Whitney[2], Joseph LeConte[3], and others, and is apparent to every observant person who traverses its borders.

The extent of the ancient lake is shown in blue on the accompanying map (Pl. XXIX). This will indicate to the reader the former geography of the region much better than can be done by description. It will be seen that the lake, during its highest stage, not only occupied Mono Valley, but overflowed northward and flooded Aurora Valley as well. At this time it had a nearly unbroken water surface 28 miles long by 18 miles broad at the widest part. Its area was 316 square miles, or three and three-fourths times that of the present lake.

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[1] This crag, at the time of making the record, November 5, 1883, was barely separated from the Negit Island. Its highest point was then 7.9 feet above the lake surface. Its northern and southern borders were abrupt, and it is formed of the same kind of rock as the larger island. The bench mark consists of a ⊥ chiseled in the rock on its southern face. The horizontal line of the ⊥ is four inches long, and was cut at the water's edge; the line at right angles to it is 10 inches long and extends up the face of the rock.

[2] Geol. Survey California, Geology, vol. 1, 1860–1864, p. 451.

[3] Am. Jour. Sci., 3d series, vol. 18, 1879, p. 37.

On looking down on Lake Mono from any commanding point one may easily restore in fancy its leading scenic features at the time of its greatest expansion, as they appeared to the ancient hunters who probably visited its shores. The waters were then fresh and rose several hundred feet higher on the precipitous sides of the mountains along its western border than at present. The peaks of the great Sierra, perhaps then known by names now long forgotten, were white with snow throughout the year and gave birth to ice rivers of great magnitude, some of which reached the shore of the lake. The magnificence of the scene when the Mono Craters were in eruption is beyond description. The ancient sea must have been ice-bound at times for many consecutive years and perhaps for centuries. Again, a change of climate would unfetter its waters and call back the sea-birds to haunt its shore. At all times its scenery was stern and wild and resembled in many ways the grander features of the fiords of Norway at the present day.

The principal island of the ancient lake—the present islands of Lake Mono being deeply submerged—was formed by Cedar Hill, which rises on the east side of the deep, narrow cañon connecting Mono and Aurora Valleys. The strait to the east of this island was much shallower than the narrower one to the west, and even during the highest water stage could not have been covered by more than seventy-five feet of water.

The topography of the basin indicates that the question whether the ancient lake overflowed or not is to be determined at the north end of Aurora Valley. At all other points the rim of the hydrographic basin of the former lake was far above its surface excepting on the pass which leads to Adobe Meadows, which is only 97 feet higher than the highest of the ancient beaches. Following Aurora Valley northward, it contracts to a narrow pass, the form of which suggests that it may have been a point of overflow. On approaching this pass the beach lines in Aurora Valley become indistinct, and it is impossible to determine from inspection alone whether the former lake extended through the gap or not. In order to decide this question a line of levels was run from the south end of Aurora Valley, where the highest of the ancient beaches is distinctly marked, to the summit of the pass. By this means it was found that the lowest point on the pass was about 100 feet above the highest water level of the former lake. Providing that no orographic movement has taken place since the waters retired, the evidence is conclusive that the lake did not find an outlet.

An observer traveling northward from Aurora Valley through the pass we have mentioned descends precipitously about one hundred and fifty feet and enters a small, level floored valley, having a playa in the center on which a deposit of a few inches of salt mingled with sodium carbonate and sodium sulphate is found during the summer

season. This little basin is completely inclosed and has faint beach lines about its borders, showing that it once held a lake at least forty or fifty feet deep. Then it probably had a free discharge northward into the valley of East Walker River, or vice versa, and was a part of the ancient drainage system of the region, but now the way is blocked by heavy lava flows which have been erupted in part from vents directly in the path of the supposed ancient drainage and in part from a conspicuous crater a few miles east of Aurora. These successive lava flows have completely dammed the drainage of the valley and they render it evident that if the ancient lake of Mono Valley had overflowed the pass at the north end of Aurora Valley its discharge would here have been stopped. One of the lava flows we have mentioned is of very recent date, and to all appearance may have been extruded in post-Quaternary times; but others are much older and probably existed previous to the maximum expansion of the lake in Mono Valley. The evidence bearing on the question of outlet thus becomes conclusive and proves that the Quaternary lake of Mono and Aurora Valleys did not find outlet and was not included in the drainage system of Lake Lahontan, as at one time supposed. What the pre-Quaternary condition of the basin may have been remains to be determined.

The shore phenomena exhibited about the borders of Mono and Aurora Valleys, in common with other lakes, consist of terraces, with their accompanying sea cliffs, gravel bars, deltas, etc.

The terraces, though numerous, are seldom conspicuous, and are without special significance excepting in the case of the highest of all, which records the maximum expansion of the ancient lake. The various terraces were originally contour lines drawn at definite horizons around the borders of the basin by the waves of the lake. They were therefore originally horizontal and parallel one with another. Measurements show, however, that they are not now horizontal, and from this it is to be inferred that some movement has taken place in the rocks forming the basin since the waters of the ancient lake evaporated.

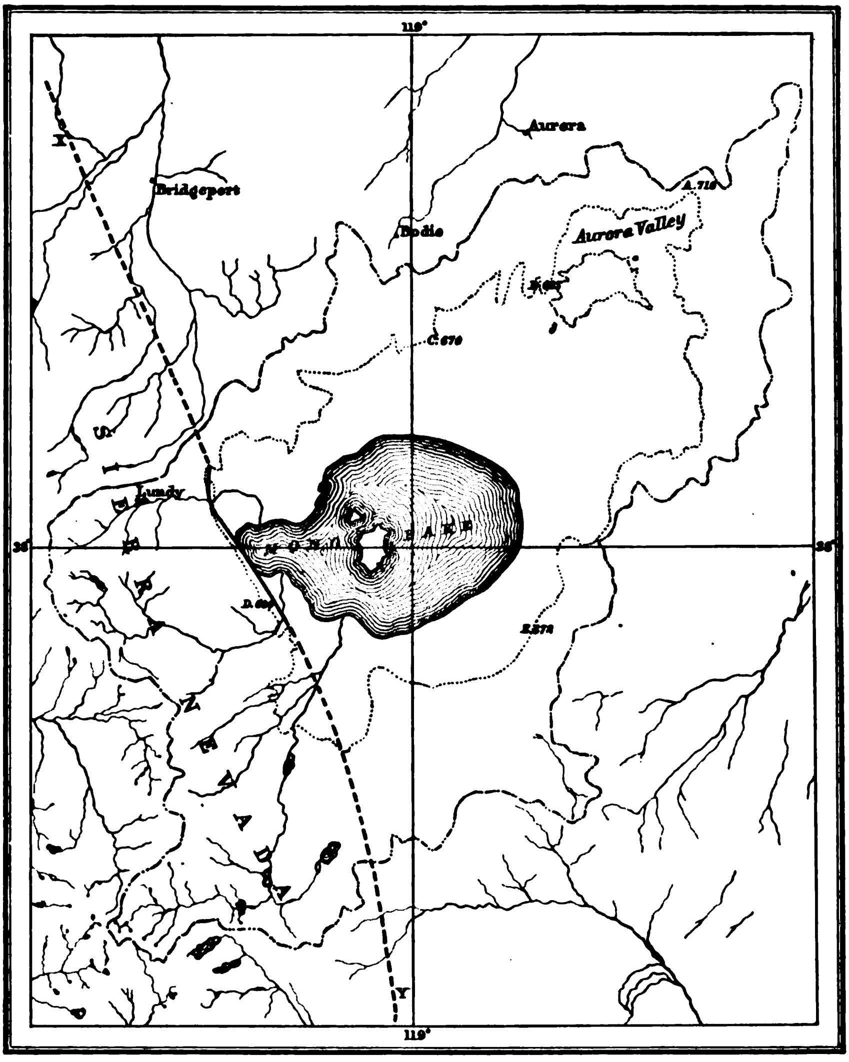
On the accompanying outline map (Pl. XXII) the elevations of various points on the highest of the ancient beaches above the 1883 level of Lake Mono are indicated. The elevations of the stations C, D, and E were determined by measurements with an engineer's level, starting in each case at the lake surface. The height of B was ascertained by sighting from C, with corrections for curvature. The elevation of A was obtained by a series of long sights starting from B, and is therefore less accurate than the measurements given for other stations in the series, but it is considered correct within a few feet. It is not always possible to determine the water line of a terrace with precision, but the probable error arising from this source can hardly exceed two or three feet at any of the stations. Allowing

for all probable errors, it yet remains evident that the terraces made by the waves and currents of the former lake at various stages, are no longer horizontal. We therefore conclude that a recent deformation of the basin has taken place.

In endeavoring to determine the character of the movement to which the deformation of the ancient beaches is due, it is necessary to bear in mind the topography and the orographic structure of the basin. The precipitous eastern face of the Sierra Nevada for at least two or three hundred miles of its course is in reality a fault scarp, although irregular and much modified by erosion. The displacement which produced this prominent topographic feature could not have been less than five or six thousand feet and was probably much greater. The course of the line of fracture across the bed of the former lake in Mono Valley is indicated by the line $x\ y$, on Pl. XXII. To the west of this line the mountain face rises abruptly from the shore of the present lake and is scored by ancient beach lines to the height of 680 feet.

That recent movement has taken place along the Sierra Nevada fault in the region of Lake Mono is suggested by the high temperature of the springs near its course and by the recent volcanic craters near at hand. Besides these less positive indications, the fact of a post-Quaternary movement is demonstrated beyond question by a fault scarp having a throw of 50 feet, which crosses the moraines and delta deposits at the mouth of Lundy Cañon, as is described on page —. Other evidence of recent disturbance near the ancient fault is afforded by the broken and contorted position of the clays forming the lake bottom to the south and southeast of the largest island. The bottom is here irregular and is crossed by fractures which have sometimes formed open fissures several feet broad. This disturbance must have been very recent, as there are no evidences of sedimentation on the disturbed surface; but whether it was caused by actual faulting or by some other disturbance has not been clearly determined.

Referring to the sketch map (Pl. XXII) it will be seen that the lowest points on the ancient beach are near the fault line but are on its northern side. It will also be observed that the beach increases in elevation all the way from the base of the Sierra to the north end of Aurora Valley. The difference in elevation of the beach line on opposite sides of the displacement, as indicated by the measurements, is less than the height of the recent fault scarp at the mouth of Lundy Cañon, and indicates that the greatest movement has been in close proximity to the line of faulting. The recent fault scarp can also be distinguished a few miles east of Lundy Cañon, where the present lake is nearest to the mountain, but has not been found in the southeastern portion of the basin. On Pl. XXII the portion of the displacement where recent movement has occurred is indi-



Rim of hydrographic basin. *Outline of Quaternary Lake.*

Post-Quaternary fault.

Scale: $\frac{1}{555,000}$

0 5 10 20 30 MILES.

MAP SHOWING RECENT DEFORMATION OF QUATERNARY LAKE SHORE.

cated by a solid line, and the probable extension of the fault both north and south by a broken line.

The simplest hypothesis which seems to explain the facts observed is that a recent movement has taken place along the fault which has resulted in a displacement of at least fifty feet. That the displacement was caused, or at least accompanied, by a subsidence of the block forming the thrown side of the fault is indicated by the present position of Lake Mono. Assuming that the basin had been undisturbed since its occupation by the ancient lake, it is evident that sedimentation would have been greatest along the southwestern border, where the creeks from the mountains empty into it, and that this portion of the depression would have been filled much more rapidly than the northern border where there are no tributaries. The present lake, under these conditions, should have been somewhat removed from the mountains, as it would have been crowded northward by progressive sedimentation. We find, on the contrary, that it washes the very base of the mountains and occupies the position that would result from orographic movement of the nature indicated by the deformation of the beach lines. The eccentric position of Lake Mono in reference to what would be its normal position had the basin remained undisturbed is in all respects similar to the abnormal position of Great Salt Lake,[1] and is due to a similar tilting of its basin.

In connection with the deformation of the ancient beaches of Mono Valley, it will be remembered that similar movements have been demonstrated in the desiccated basins of Lakes Bonneville and Lahontan. The sediments of these ancient seas are also broken by fault scarps of more recent date than any of the old lake records. Mono Basin thus illustrates, on a small scale, the character of the recent orographic movements that have affected at least half, and probably the whole, of the Great Basin.

The fault on the west side of Lake Mono occurs at the immediate base of the lofty Sierra, and all the stream-borne material carried into the lake from the mountains is transferred from its upheaved to its thrown side. The shifting of load from one side of the fault to the other by the action of ice and water since the present topography of the region was initiated has been very great, and has tended to produce such a movement of the faulted blocks as has been observed. The melting of the névés and glaciers which formerly covered the mountains would also act in the same direction. This transfer and variation of load may be considered in part, at least, as the cause of the recent movement, but the commencement of the faulting must have occurred before any considerable transfer of load could have taken place, and is probably due to other causes.

[1] See Contributions to the History of Lake Bonneville, by G. K. Gilbert, U. S. Geol. Survey, Second Ann. Rep., 1880–'81, p. 198.

The variations of surface temperatures, weight of water in ancient lake basins, transfer of load from the heaved to the thrown side of a fault, etc., by which the movements of faults have been explained by various writers, it seems to me are all secondary results of some great, slow-working and wide-reaching series of forces which have made themselves felt not only in the basins of Lakes Mono, Bonneville, and Lahontan, but throughout the Great Basin and in various other parts of the world as well. The nature of the evidence appears to point to the conclusion, already familiar to geologists, that internal changes of temperature in the earth's mass are the primary causes of the faulting of its crust.

What the original altitude of the highest of the ancient beaches of Mono Valley may have been it is now impossible to determine with accuracy. Considering the elevations of C and D (Pl. XXII) as representing the maximum height of the ancient beach above the present lake and adding to this the present depth of Lake Mono—but not considering the amount of recent sedimentation that has taken place—we have 827 feet as, approximately, the maximum depth of the lake at the time the highest of the ancient beaches was formed.

The gravel bars constructed by the waves and currents of the former lake are in some instances fine examples of this class of shore phenomena; but, so far as our studies have shown, they are of little significance in reference to the Quaternary history of the basin. The shores of the lake during its highest stage were abrupt on all sides, but in the vertical interval between the present water surface and a horizon about fifty feet below the highest of the ancient water lines, the lake was confined on the north side of Mono Valley by a sloping plain, thus producing very favorable conditions for the formation of works of construction through the action of waves and currents. In this portion of the basin a series of low, level-topped ridges of gravel, several miles in length and usually from seventy-five to one hundred feet broad, sweep about the border of the basin in concentric curves, concave southward. The symmetry of these long curves attracts the eye from commanding points and relieves the monotony of the scenery in this desert-like portion of the valley. In riding over these ridges one finds that many of them are natural highways of a most excellent character. The material of which they are composed is mostly well-rounded gravel, which was derived in part from the pre-existing alluvial cones and in part from the waste of the sea cliffs on the border of the region of accumulation. The sand dunes in this portion of the basin are also the indirect result of the transporting power of currents, as the material of which they are composed was accumulated during the time the former lake occupied the valley.

The ancient water levels recorded by the bars north of Lake Mono, as well as the numerous terraces on other portions of the basin, show

that the former lake lingered at many horizons during its rise and recession. The shore phenomena are on a small scale in comparison with the similar records left by Lakes Bonneville and Lahontan, for example, and in themselves do not show that the ancient lake had more than one high-water stage. The question of ancient oscillations of level in the waters that occupied the basin will claim attention, however, after we have considered the glacial phenomena of the region.

The deltas formed at the mouths of the tributaries of the ancient lake will be described in connection with the glacial moraines, with which they are intimately associated. Their principal interest is in connection with the overlap of the lacustral and glacial records.

SEDIMENTS.

That Mono Valley once held a water body of broader extent than at present is shown not only by the beach lines on the interior of the basin but by lacustral deposits, which evidently fill it to a great depth. One of the best localities for studying these deposits is on Paoha Island. To an observer from the shore the two main islands in the central portion of the lake exhibit a marked contrast of color, as mentioned in the preliminary portion of this paper, the central and higher portions of the larger being light gray and appearing almost white in comparison with the smaller, which is nearly black. The explanation of this contrast lies in the fact that the larger island is deeply covered with lacustral sediments, while the smaller is composed entirely of dark lava. The highest portion of Paoha Island is composed of light gray lacustral clays, at times thinly laminated and containing layers of diatomaceous earth. These beds have been much eroded and now form "bad lands" in miniature. In some instances the lamination of the strata is rendered conspicuous by alternating sheets of white diatomaceous earth and buff-colored marl, also rich in microscopic organisms, the layers of each being so thin and even that a hand specimen might easily be mistaken for fossil wood of coarse grain.

The thickness of the sedimentary beds exposed on the island can not be determined with accuracy, but it is probably between two and three hundred feet. Their original thickness, however, must have far exceeded this, as they have suffered much from erosion. On the east side of the island the lacustral strata form bold bluffs, which are being eaten away by the waves in such a way as to expose fine sections of the deposit and reveal dislocations and contortions that have been produced since the beds were laid down. Wherever the shore of the island is composed of lacustral sediments a broad cut-terrace has been formed, which is now covered by about twelve feet of water. This terrace not only illustrates the greater ease with which the clays are eroded in comparison with the volcanic rocks

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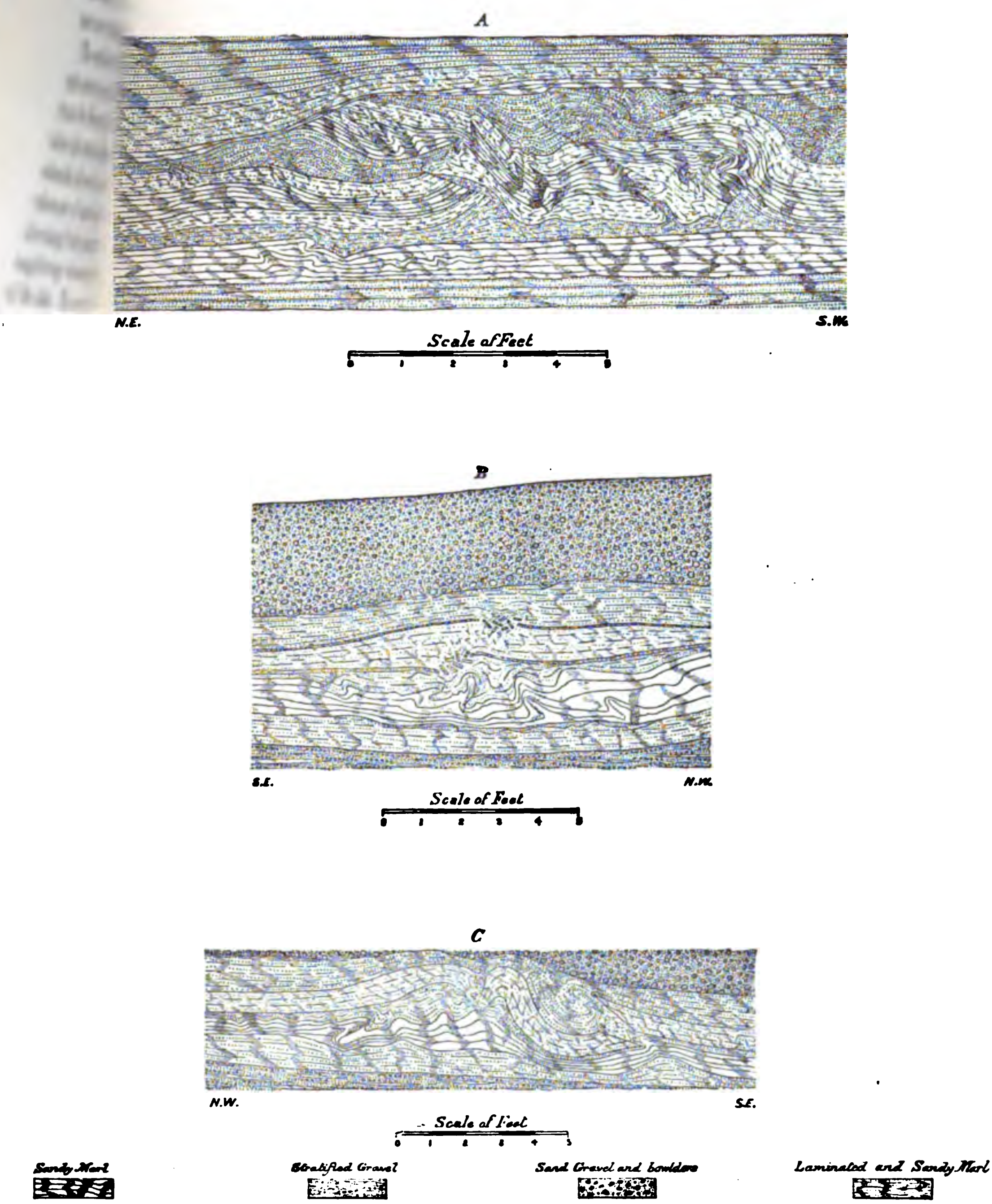
shown in a fresh cut made by the [illegible]
between the mouths of Leevining and [illegible]
lowing section is exposed:

1.	Brown sandy loam, forming the surface	[illegible]
2.	Marly clay, with thin, white crusts of calcium carbonate	[illegible]
3.	Light colored marl	[illegible]
4.	Volcanic lapilli	[illegible]
5.	Light colored marl	[illegible]
6.	Fine, white, pumiceous dust	[illegible]
7.	Sharp angular lapilli	[illegible]
8.	Evenly stratified, sandy marl, jointed	[illegible]
9.	Coarse bedded gravel, containing coarse granitic debris	[illegible]
10.	Sand, ripple marked	[illegible]
11.	Sandy clay	[illegible]
12.	Quartz sand, with gravel	[illegible]
13.	Evenly stratified sandy marl (like No. 8)	[illegible]
	Distance to lake, about 20 feet.	[illegible]

In this section, the strata numbered 8 and 13 are typical lacustral [illegible], evidently accumulated in deep, still water, while those [illegible] 9 to 12, inclusive, indicate shallow water conditions [illegible] have been deposited when the lake was low. In our inter[illegible] of the section we have considered the coarse shore material [illegible] the lake beds as corresponding in position to the medial [illegible] of Lakes Bonneville and Lahontan. The strata numbered



W J McGee, Del

I C Russell, Geologist

CONTORTED LACUSTRAL SEDIMENTS.

forming portions of the border of the island, but evidently indicates that a rise in the lake surface or a depression of the island has followed a period of considerable length during which the water was stationary at one horizon, thus allowing the waves to carve the terrace now submerged.

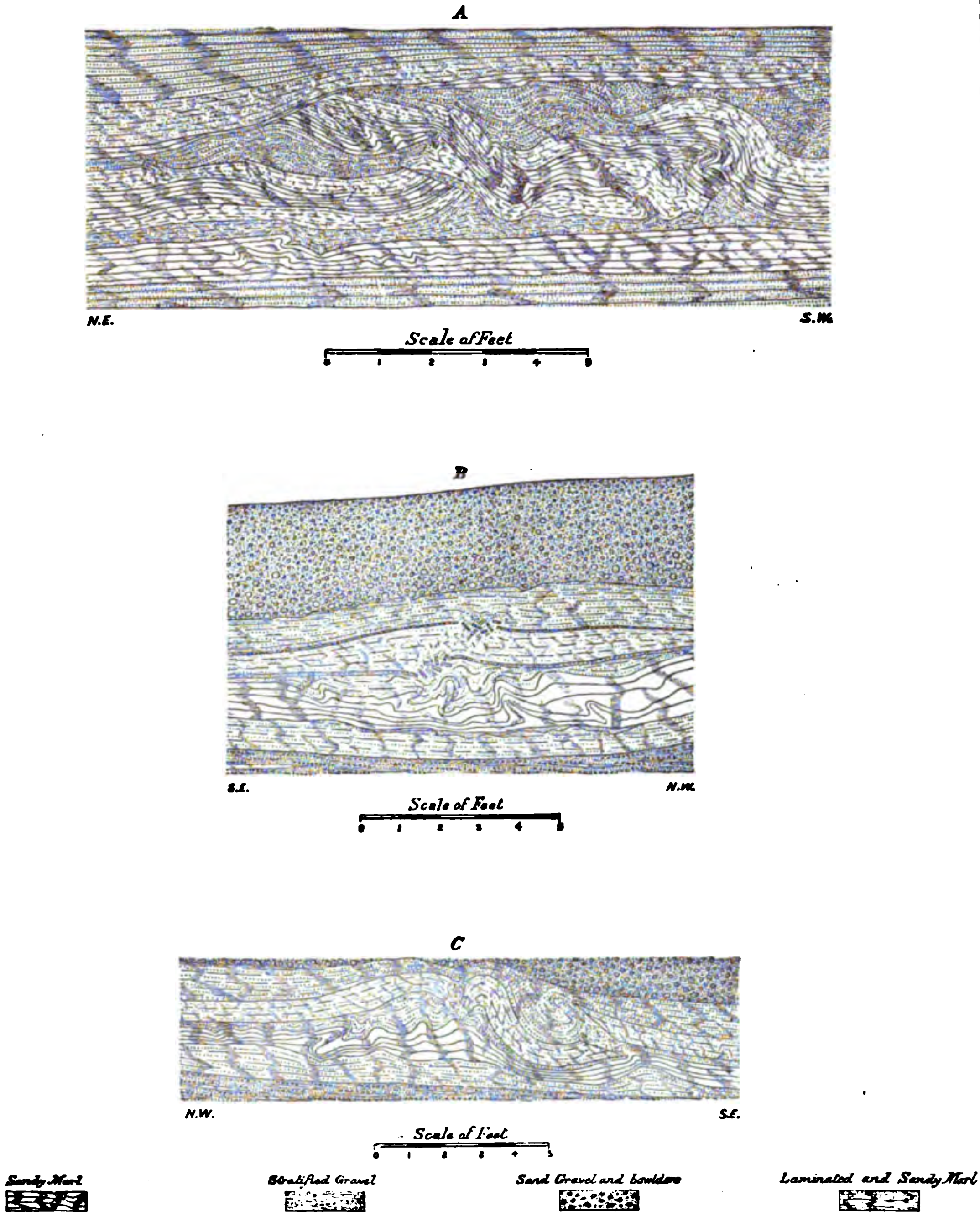
The sediments of the ancient lake are also exposed in the channels carved since the recession of its waters by the creeks flowing from the Sierra Nevada. Owing to the proximity of the ancient shore the strata deposited in this portion of the basin exhibit considerable diversity, some of the beds being of fine marly clay, while others are of sand and coarse gravel. In the section exposed at Leevining Creek partings of volcanic ash indicate that some of the neighboring volcanoes were in eruption at a late date in the history of the lake. The lower portion of the channel of Rush Creek has been excavated in lacustral sediments together with deposits of lapilli and pumiceous dust derived from the Mono Craters.

These exposures exhibit over one hundred and fifty feet of sediments, including at some localities medial partings of coarse gravel. The occurrence of two divisions of fine lacustral sediments with coarse gravels between indicates two separate high water stages, with an intervening period during which the lake was low and gravels were swept out over the fine sediments previously deposited. This is best shown in a fresh cut made by the waste water of an irrigating ditch, between the mouths of Leevining and Rush Creeks, where the following section is exposed:

		Feet.
1.	Brown sandy loam, forming the surface	3.0
2.	Marly clay, with thin, white crusts of calcium carbonate	0.6
3.	Light colored marl	2.0
4.	Volcanic lapilli	0.1
5.	Light colored marl	0.4
6.	Fine, white, pumiceous dust	0.1
7.	Sharp, angular lapilli	0.3
8.	Evenly stratified, sandy marl, jointed	40.0
9.	Current bedded gravel, containing coarse granitic débris	3.0
10.	Sand, ripple marked	1.0
11.	Sandy clay	1.1
12.	Quartz sand, with gravel	3.0
13.	Evenly stratified sandy marl (like No. 8)	5.0
		59.6

Unexposed to lake, about 50 feet.

In this section, the strata numbered 8 and 13 are typical lacustral sediments, evidently accumulated in deep, still water, while those numbered from 9 to 12, inclusive, indicate shallow water conditions and must have been deposited when the lake was low. In our interpretation of the section we have considered the coarse shore material parting the lake beds as corresponding in position to the medial gravels of Lakes Bonneville and Lahontan. The strata numbered



W J McGee, Del I C Russell, Geologist

CONTORTED LACUSTRAL SEDIMENTS.

4, 6, and 7 were formed by showers of lapilli or volcanic ashes which fell in the lake.

The marls and clays occurring at a distance from the mountains are finer and more homogeneous than those exposed in the sections observed on the south side of the basin. A sample of light-colored marly clay, rich in diatoms, from an exposure about two miles east of Warm Spring, which may be considered as typical of the lacustral strata of the basin, has been analyzed by F. W. Taylor, who reports its composition to be as follows:

Analysis of lacustral clay.

Constituents.	Per cent.
Silica, SiO_2	61.80
Iron protoxide, FeO	3.57
Alumina, Al_2O_3	12.86
Lime, CaO	5.10
Magnesia, MgO	2.88
Sulphuric acid, SO_3	0.48
Sodium chloride, NaCl	1.17
Potash, K_2O	1.20
Soda, Na_2O	3.49
Phosphoric acid, P_2O_5	Trace
Water, H_2O	8 25
Total	100.30

The lacustral beds at numerous exposures exhibit local faults having a throw from a fraction of an inch to several feet, and they are sometimes contorted in a most remarkable manner. On Pl. XXIII, the appearance of contorted strata as seen in cross sections has been reproduced from field sketches made by W J McGee. These figures illustrate the character of a class of disturbances common in superficial beds, not only of Mono basin, but in the sediments of other Quaternary lakes of the region.

In Fig. A, Pl. XXIII, a portion of the section exposed by the erosion of Rush Creek is represented. These beds include marly clay, sand, and volcanic dust in various degrees of admixture. The medial portion of the section, comprising a band about four feet thick, has been compressed, crumpled, and broken, while the inclosing strata, both above and below, remain horizontal. The disturbance in this instance may be traced horizontally for several hundred feet. Similar disturbances occur at two or three other horizons at lower levels along the banks of the same stream. The details of the scrolled and contorted lines formed by the exposed edges of the crumpled strata vary throughout the disturbed layers, and at no two points would they be found to agree; but the general character of the deformation as seen in cross-section is well shown by the figures given on the accompanying plate.

The sections B and C, on the same plate, are sketches of exposures seen in the same stratum on the opposite sides of the gorge carved by Mill Creek through the sediments of the ancient lake. In these sections, as in those observed near Rush Creek, the contorted layers are mainly composed of clay and sand and are inclosed between unconsolidated strata in which no disturbance can be detected. This locality is near the extremity of the moraine extending into the valley from the mouth of Lundy Cañon, and the upper portion of the section is composed of coarse débris washed down from the glacial deposit. It is not necessary to describe these sections in detail, since they are very similar in essential features to the exposure illustrated by Fig. A and are accurately shown in the drawings. Examples of contorted beds of the same character might be multiplied, as they are common in the sediments of the basin, but this would merely increase details without adding materially to our knowledge of the phenomenon.

In the sections described above, it is manifest that differential movement has taken place among the strata since they were deposited. Observations of the writer show, however, that there are other beds of essentially the same character, similarly contorted, which fall in a different category.

On the right bank of Leevining Creek, about a mile from the lake, an irrigating ditch returns to the creek, and has cut a deep notch in the side of the cañon, which exposes a fresh section of about eighty feet of gravel, sand, and clay, belonging to the sedimentary deposits of the former lake. A portion of the upper part of this section is shown on Pl. XXIV. In this exposure, as in those already noticed, the strata above and below the contorted layer are horizontal and undisturbed; and, from the evenness of their lamination and their ripple-marked surfaces, it is evident that they were deposited in comparatively quiet waters. There are two contorted layers in this section, separated by four and a half feet of gravel. The upper one only appears in the pictorial portion of Pl. IX. This is a layer a little less than three feet thick, composed principally of fine sand with thin clay seams and iron stained layers running through it. These thin layers are harder than the sand itself and serve to accent the crumpling that has taken place. The lines appearing in the section are the edges of thin sheets so contorted and convoluted as to form extremely intricate patterns. The iron stained layers are especially noticeable and may be traced from end to end of the section without once being broken or disconnected except by a few irregular joints. These harder layers frequently form pockets or oval cells, having a diameter of several inches, which are completely filled with loose sand and pebbles; this loose material is of a different character from the layers inclosing it and runs out freely when the cell walls are broken. The section shown on Pl. XXIV is approximately east and

west in trend, or nearly parallel with the ancient lake shore as indicated by the beaches on the neighboring moraine. It differs from the sections of contorted beds previously described in that the contorted lines running through it are not broken, but are continuous, although greatly crumpled and sometimes folded back on themselves in the most complicated manner, and also in holding pockets of sand and gravel which are coarser and less compact than the material forming the inclosing layers. Our studies lead to the conclusion that the contortion in this instance took place at the time the beds were deposited, and is not a result of subsequent movement, as in the other cases cited.

The cause of the contortion of the strata in each of the classes mentioned remains an enigma, although several hypotheses may be suggested in explanation.

The contortions exposed in the bank of Rush Creek were observed several years since by Joseph LeConte, who published a sketch of them.[1] In explanation of the disturbance LeConte observes:

> This crumpling and scrolling of the strata could have been produced only by a glacier advancing on a bed of stratified clay, or else by the pushing of icebergs on a stratified lake bottom.

As a similar explanation has been advanced by various writers in reference to contortions in superficial strata in widely separated regions, especially in the drift-covered part of the Eastern States,[2] it is important to determine definitely whether such an explanation is admissible or not in the case of the phenomena observed at Rush Creek. The positions of the glaciers which formerly advanced into that portion of Mono Valley which is adjacent to Rush Creek are well known, and it has been positively ascertained that they did not reach within two or three miles of the locality at which the contorted beds occur. There are no bowlders or glaciated stones in the section or in its neighborhood to indicate that either glaciers or icebergs were concerned in producing the disturbance. Even if our observations were not decidedly in opposition to this hypothesis, it would be difficult to conceive how a glacier or a stranded iceberg could crumple the superficial layer of a series of unconsolidated sands and clays over a broad area without disturbing the subjacent strata. This objection is especially forcible in cases where the disturbed layers are only a few inches in thickness and occur at several horizons. More than this, precisely similar contortions have been observed many times by the writer in the unconsolidated sediments of Lakes Bonneville and Lahontan, at localities entirely without the region of possible glaciation.

[1] Am. Jour. Sci., 3d series, vol. 18, 1879, p. 40.

[2] Good illustrations of contorted beds in the Quaternary deposits of New York State were published nearly half a century ago by Lardner Vanuxem: Geology of New York, Part III, Survey of Third district, pp. 214, 215.

It is not probable that all the observed examples of contortion are due to one cause. In considering the various agencies that may have produced them we should take account of the influence of superimposed beds, which, in some cases, as in deltas and gravel embankments, are known to produce a local crumpling of the strata on which they are deposited. Abundant illustrations of contortion produced in this manner are to be seen in many of the desiccated lake basins of the Far West. In some cases, however, the contorted layers are near or at the top of a section and have not been buried beneath deposits of any kind. In such instances it seems safe to assume that their disturbed condition is due to the manner in which they were deposited; perhaps they were laid down in disturbed waters where the conflicting waves and currents produced a chop sea.

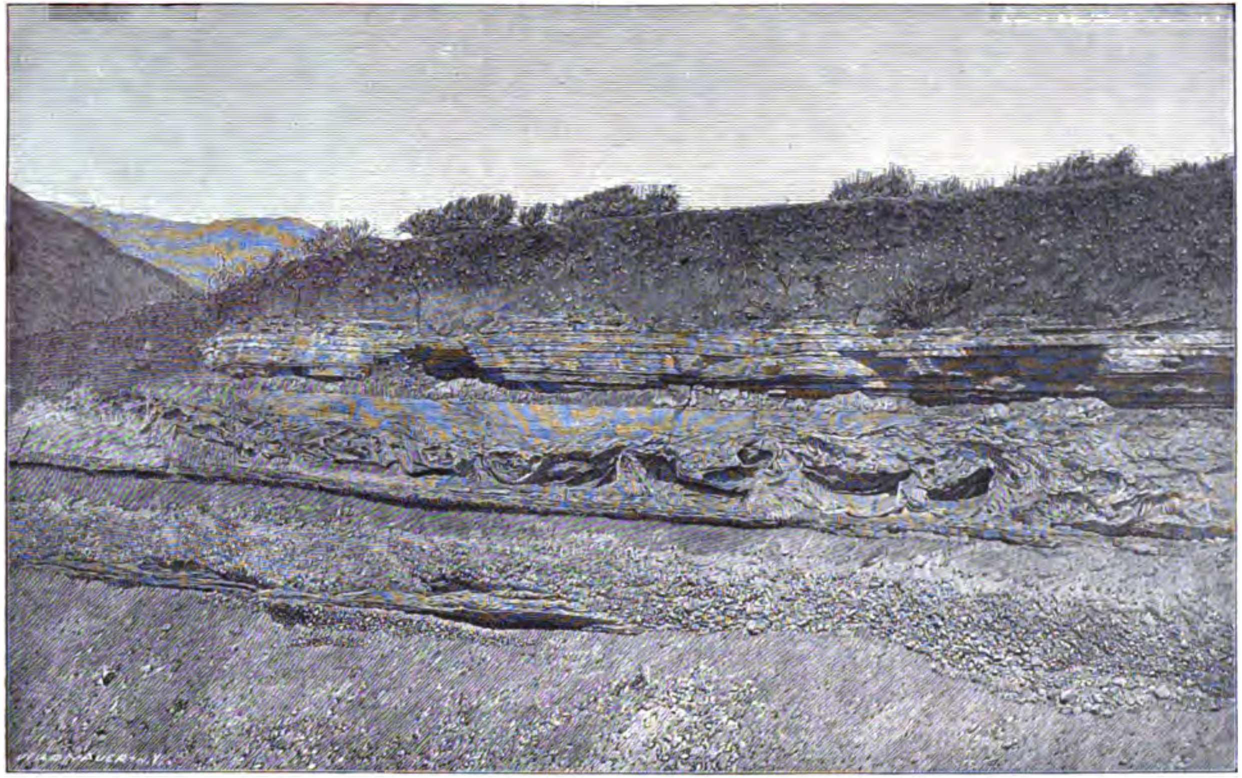
Movements of the ice which forms on lakes during cold weather, if the water be shallow enough to allow it to rest on the bottom, may produce a disturbance in the superficial layers of sediment similar to those noted above. Such an occurrence, we conceive, may have been the cause of the class of disturbances illustrated at Rush Creek. It is probable also that in some cases the crumpling was produced by a movement of large masses of stratified beds along certain planes, the position of which would be determined by the character of the material composing the various strata. All these suggestions fail, however, in the case of the Leevining Creek exposure, where the contorted layer contains pockets of clean loose sand and gravel.

CHEMICAL DEPOSITS.

At many localities about Lake Mono, as mentioned in our introduction, there are rugged crags and tower-like masses of calcareous tufa which were deposited when the valley held a much larger lake than at present. Besides these more prominent masses there are accumulations of the same chemical composition occurring as a cement in the gravel of some of the terraces and beaches about the borders of the valley.

The cementing material in the beaches is a compact stony tufa, and is found from the surface of the present lake up to within a few feet of the highest of the water lines on the sides of the basin. It was never abundant and can now be seen at only a few localities. Its wide vertical range indicates that the lake during the greater part of its history was saturated with calcium carbonate. This does not imply that the waters were strongly charged with chemical substances, however, as a similar precipitate is now forming in Pyramid and Walker Lakes, Nev., which contain less than half of one per cent. of saline matter in solution.

The isolated tufa crags of the ancient lake that we are studying are confined to Mono Valley and occur mostly in the immediate neighborhood of the present lake. Some of them, as has been men-



CONTORTED LACUSTRAL STRATA NEAR LEEVINING CREEK.

Approximate scale, $\frac{1}{80}$. From a photograph.

tioned in the introductory sketch, stand in the lake, and are partially or wholly submerged.

These deposits occur as irregular crags and tower-shaped masses, sometimes forming groups of large size, as may be seen near Warm Spring. The individual towers deposited about a single spring are frequently from ten to forty feet in diameter, and sometimes have a height of from forty to fifty feet. The masses least weathered indicate that their original form was tower-like, with a rounded or dome-shaped top. Owing to the manner in which the individual masses are grouped and blended one with another, as well as to the disintegration that has resulted from weathering, the primitive shape of these deposits is now seldom clearly shown.

The calcareous tufa of Mono basin exhibits three divisions, which correspond to the varieties occurring in the Lahontan basin, but do not succeed one another in the same order.[1] The inner core is invariably composed of a stony variety, described in the reports referred to as lithoid tufa; this forms tubes or tubular and porous masses, many feet in thickness. The tubes when distinct have an inner diameter varying from a fraction of an inch up to twenty or thirty inches; in the larger specimens the walls are frequently six or eight inches in thickness. The tubes as we now find them are usually filled with amorphous tufa, but occasionally contain selenite crystals. With the exception of the filling, the inner core of the tufa crags and towers about Lake Mono corresponds in all respects with the structures of similar shape now standing in the lake near Black Point, through which spring waters are still flowing. The evidence is so complete that there is no room for doubting that nearly all the tufa masses in the basin began as sublacustral spring deposits and were subsequently coated with tufa of other varieties, precipitated directly from the waters of the lake.

Enveloping the core of lithoid tufa which forms the center of each of the tufa crags, there is a second deposit of calcium carbonate, usually having a dendritic structure, which is again enveloped in a layer of thinolite crystals. In Lahontan basin, it will be remembered, the main deposit of dendritic tufa invariably covers the thinolite, and in some cases this is the order in the Mono deposits.

The character and succession of the tufas found in Mono Valley will perhaps be best presented by describing two localities where the succession is well shown.

The first example to claim attention occurs at the water's edge at the western end of the long, symmetrical curve formed by the north shore of the lake. The tufa at this locality has built up a compound crag about twenty-five feet high, which is now broken and weathered in such a manner as to reveal its internal structure with great distinct-

[1] See a sketch of the Geological History of Lake Lahontan, Third Ann. Rept. U. S. Geol. Survey, 1881-'82, p. 215; and Geological History of Lake Lahontan, etc., Mon. U. S. Geol. Survey, No. XI.

ness. The core of each of the separate towers composing the mass is about four feet in diameter and composed of tubular lithoid tufa. Outside of this is a coating of dendritic tufa ten inches thick, formed in successive layers. Next is a layer of thinolite crystals, four inches thick, passing into a second zone of dendritic tufa twenty inches thick. Following this is a dense layer, having the structure and appearance of lithoid tufa, one inch thick. Outside of this thinolite crystals form an envelope three feet in thickness. The sheathings were deposited one after another about the central core, which they completely envelop, and arching over the top of the tower, they form a low dome. The deposition of the various layers evidently took place in the waters of the same lake, as no evidence of a break in the process is indicated by weathering or unconformity of any kind. After all the layers described above were formed, the lake receded and the deposit became much broken and weathered. The waters then rose sufficiently to submerge the structure, and another layer of lithoid tufa, between one and two inches thick, was deposited. A somewhat idealized cross-section of one of the separate towers of this mass is represented in the following diagram, in which the dotted lines represent a portion removed by weathering previous to the deposition of the last sheathing of lithoid tufa.

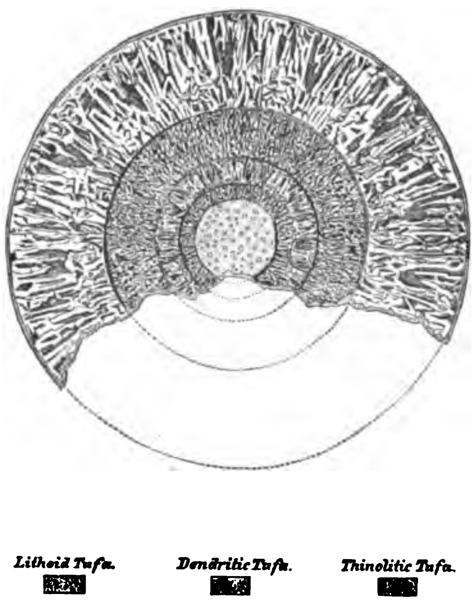


FIG. 1.—Horizontal section of a tufa tower.

The second locality of characteristic tufa deposits to which we desire to direct attention is about a mile east of Warm Spring, and has already been noticed briefly in the introduction to this paper, page 274. The tufa crags are there elevated about two hundred feet above the lake and rise forty or fifty feet above the deposits of marl and lapilli by which they are surrounded. They are scattered, either singly or in groups, over an area several hundred acres in extent. Many of them are so weathered and broken that their internal structure is clearly revealed. The inner core, as is the case with the similar crags throughout the basin, is of tubular lithoid tufa, the separate tubes being frequently twelve or fourteen inches in diameter, with walls five or six inches thick. This inner core is commonly from one

foot to ten or even twelve feet in diameter, and in a single observed instance it exceeds twenty feet. Enveloping the lithoid tufa is a layer of thinolite crystals from four to six feet thick, which exhibits many alternating bands of coarse and fine crystals. There is no envelope of dendritic tufa outside the thinolite, but at times the core of lithoid tufa exhibits a tendency toward a branching or dendritic structure. A vertical section through one of these masses is shown in the following sketch, the scale of which is approximately ten feet to the inch.

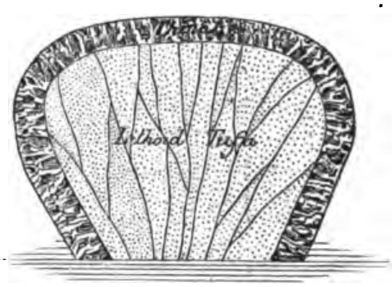


FIG. 2.—Vertical section of a tufa dome.

At a few localities the inner core of the tufa crags is composed of a single tube of lithoid tufa, sometimes less than ten inches in diameter, with walls two or three inches thick, about which two or three feet of thinolite crystals have been deposited. In such instances the crystallized tufa nearly always arches over the top of the tube, but a few examples were observed in which the central opening extended through the thinolite layer, indicating that the sublacustral spring which built up the central tube continued to flow while the thinolite crystals were forming.

The highest thinolite observed in the basin has an elevation of 270 feet above the present lake; but as the deposit occurs in isolated masses, it can not be asserted positively that this is its maximum limit. There is no clearly defined terrace coincident with the elevation of the highest thinolite to indicate that the lake held a definite horizon during the time this variety of tufa was being deposited. The upper limit of the dendritic tufa is also indefinite, and it has not been determined whether it reached as high on the sides of the basin as the thinolite or not. As many crags near the lake surface are without sheathings of dendritic tufa, while others at a higher level may or may not be coated by it, it is evident that the various local deposits are not all of the same age. Those rising in the lake near Black Point, for example, are composed entirely of lithoid tufa, in all respects similar to the inner cores of many of the larger towers, and must have been formed after the thinolitic and dendritic tufas had been deposited. It thus appears that the tufa precipitated directly from the lake waters was formed about the nuclei furnished by the spring deposits, and that the older ones became enveloped with both the thinolitic and dendritic varieties, while the later ones were coated with thinolite alone, and the latest of all left without subsequent deposits.

The shores of the ancient lake, during the stages that witnessed the formation of the thinolitic and dendritic tufas, were not composed of solid rock, except between Leevining and Mill Creeks, and

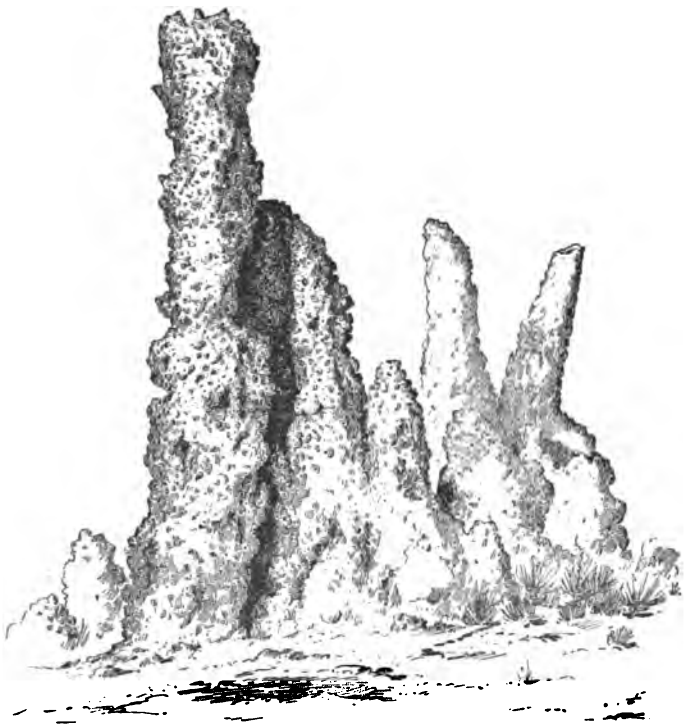
were in general unfavorable for the accumulation of calcareous deposits, for the reason that a solid nucleus is requisite to initiate crystallization and to form an anchorage for the tufa deposits during their growth. The rocks on the western shore of the lake were coated with dendritic and thinolitic tufas, but the deposit is now much weathered and broken. It has become almost entirely displaced from its original position on the cliffs, and consequently furnishes but little information in respect to the height it formerly attained on the sides of the basin.

The character of the tubular lithoid tufa mentioned in the preceding descriptions is well shown on the southern shore of the lake, about a mile east of the end of the Mono Craters. Several acres at this locality are covered with irregular tubular trunks, from a few inches to five or six feet in height, with a diameter of six or eight inches. The appearance of a few of these peculiar deposits is shown on Pl. XXV. The formation as a whole resembles a forest of gnarled and contorted trunks and stumps changed to stone. The trunk-like masses are not simple tubes with solid walls, but are traversed by many irregular passages which open at the top in a number of small orifices. They are porous and cellular throughout. On the sides there are also numerous openings about which tufa has been deposited, thus forming knobs and irregularities. At times, two or more separate trunks are united by lateral branches, but usually each one is the result of a single independent growth. These tubular trunks differ, however, from the core of lithoid tufa in the larger crags, in that they spring from independent bases and are spread over a broad area, instead of being grouped about a common center and united so as to form a single mass, expanding sheaf-like at the top.

The impression which this imitation forest leaves on the mind is that it is in some way weird and uncanny. The silent and motionless trunks with their uncouth shapes recall Dante's description of the wood of the suicides. This fancy is heightened by the proximity of a sea whose flowerless shores seem scarcely to belong to the habitable earth.

The tufa about Lake Mono corresponds not only in general appearance and in structure with the similar deposits in Lahontan basin, but also in chemical composition. Analyses of several samples show that all of the varieties, disregarding what may be considered as accidental impurities, consist essentially of calcium carbonate. Some of the tufa near Lake Mono has been calcined and found to form an excellent lime.

The history of the crags and tower-like masses of tufa in Mono Valley may be briefly stated as follows: They commenced with the deposition of porous and tubular lithoid tufa from the waters of sublacustral springs. The cones and tubular masses thus formed were subsequently enveloped in sheathings of the dendritic, thinolitic, and



TUFA TRUNKS ON SOUTH SIDE OF LAKE MONO.
Height of main trunk, five feet. From a photograph.

lithoid varieties, precipitated from the lake waters. The varying character of the sheathings seems to have depended on the strength of the solution from which precipitation took place. We can not conceive of changes in the actual composition of the lake waters corresponding with the various tufa bands observed. The general chemistry of inclosed lakes renders it evident that the alternations in the character of the precipitate indicate variations in the strength of the solution or else that the crystalline or non-crystalline character of the precipitate depended on temperature. At present we are at a loss to know why at one time the tufa should have a beautifully dendritic structure, at another time form regular and symmetric crystals, and still again be a structureless, stony mass, each deposit having the same composition and being evidently formed from the same solution. This brings us to the special consideration of thinolite.

THINOLITE.

The study of the tufa deposits of Lake Lahontan has shown that there is no reason for considering the lithoid and dendritic varieties as having been altered in chemical composition, with the exception of slight superficial weathering, since they were precipitated. The thinolite, on the other hand, is considered as an alteration of crystals, the original forms of which have been preserved while their chemical composition has changed.

The name thinolite was first applied to this mineral by Clarence King, in his Report of the U. S. Geological Exploration of the 40th Parallel (volume 1, p. 508), in which Lake Lahontan was first described. In the study of that lake carried out by the present writer many specimens of thinolite were collected. These, together with samples of the same mineral from Mono Valley, were submitted to E. S. Dana for crystallographic study. The results of his investigations have been published in Bulletin No. 12 of the U. S. Geological Survey, from which a large portion of the following description has been taken, and to which the reader is referred for a more detailed discussion of the nature of thinolite than is here practicable. Plate XXVI, illustrating the structure of thinolite, has been reproduced from drawings published in the bulletin referred to. Other illustrations, representing especially its external appearance, will be found in the reports of the U. S. Geological Exploration of the 40th Parallel, in the Third Annual Report and in Monograph No. XI, of the U. S. Geological Survey.

The crystals from various localities in Lahontan and Mono basins present considerable diversity in superficial appearance, some being open and friable, with individual crystals clearly defined, while others are as dense and compact as ordinary limestone, and reveal the individual crystals of which they are composed only when partially dissolved, as in weathering, or when their surfaces are polished.

But, however varied the specimens from different localities may appear at first glance, a close examination reveals the fact that they all agree in crystalline form. They are all composed of tetragonal pyramids, usually packed one within another, so as to produce an elongated, prism-like crystal, as shown in a number of the figures on Pl. XXVI. No doubly terminated crystals have been observed. Even the prism-like forms, at times eight or ten inches in length, which appear to be simple crystals, are formed of hollow pyramids placed one within another. This imbricated structure is shown in Figs. 17, 20, 21, 27 and 28, Pl. XXVI, and by the cross-sections of crystals in the same illustration. The cross-sections exhibit the edges of the hopper-shaped pyramids which form the compound crystals; these appear as a series of concentric rectangles, crossed by diagonal lines, as is shown by the figures at the bottom of the accompanying illustration. The plates forming the pyramids and the diagonals are composed of compact calcite, and are shown in white in the illustrations. Some of the crystals are enveloped in a coating of amorphous tufa, as represented on Figs. 5, 16, and 22, Pl. XXVI, which is of much later date than the thinolite it incloses, and has served to preserve the structure. We are able to cut thin transverse sections of these incrusted crystals and polish the surfaces thus obtained without disturbance of the plates within. However compact and irregular the thinolite may appear at first sight, the imbricated structure described above is always apparent when the specimens are critically examined, and reveals the form of the original mineral after which it is a pseudomorph. This, as determined by Dana,[1] was a tetragonal pyramid or octahedron, measuring over the summit 35 degrees, and consequently having a terminal pyramidal angle of 95½ and a basal angle of 145 degrees.

That thinolite is a pseudomorph, and not the original mineral deposited from the waters of the ancient lakes in the basins of which it is found, is indicated by the replacement revealed on microscopic examination, and by its open cellular structure, which makes it evident that a portion of the original crystal has been dissolved away. A critical study of its crystalline form, it was hoped, would decide what the original mineral may have been; but in connection with this subject Dana says:[2]

> The description of the original crystalline form of the thinolite, so far as can be made out, is sufficiently complete to give an emphatic negative answer to the question as to the nature of the original mineral. It was not gaylussite, nor gypsum, nor anhydrite, nor celestite, nor glauberite, nor, in fact, any one of the minerals which might suggest itself as a solution of the problem. The crystalline form is totally irreconcilable with any one of these. This is so clear, from what has gone before, that the question admits of no argument at all. But more can be said. The original mineral was one which does not appear thus far to have been observed in

[1] Bull. U. S. Geol. Survey, No. 12, p. 21.
[2] Ibid., p. 22.

its natural condition, although, as will be shown later, it probably has occurred abundantly at numerous other localities. Furthermore, a review of all the artificial salts of calcium, sodium, and magnesium has failed to bring to light any one which would satisfy the conditions required.

Although it has not been possible to determine the precise nature of the original mineral, yet we have some indication of its character. Dana observes that—

The open skeleton forms, consisting now of crystallized calcium carbonate, make it seem very probable that the original mineral was a double salt, and that a salt containing calcium carbonate as one of its members. Only on such a supposition is it easy to understand the removal of so large a part of the original material and the leaving behind of these plates of calcium carbonate marking the original crystalline structure.

In the Bulletin from which the above quotations were made, the suggestion is offered, but without intending it as more than a provisional hypothesis, that the mineral of which thinolite is an alteration may have been the chloro-carbonate of calcium, isomorphous with phosgenite, the chloro-carbonate of lead; that is, a mineral having the composition $CaCO_3+CaCl_2$, isomorphous with $PbCO_3+PbCl_2$, and now altered to $CaCO_3$, as is the phosgenite to $PbCO_3$.

The magnitude of the thinolite deposits of the Lahontan and Mono basins assures us that the mineral formerly associated with calcium carbonate in the crystals now changed to thinolite must have been present in immense quantities. We know also that it must have been contributed principally by the inflowing streams. Analyses of the waters of the present lakes of Lahontan and Mono basins and of some of the tributary streams show that the most abundant salts in the lakes formerly occupying these basins must have been sodium chloride, carbonate, and sulphate, while the quantity of calcium chloride must have been comparatively small. Moreover, had calcium chloride been present in quantity in the ancient lakes we should expect to find it in the present lakes of the same basins, or, supposing that the lakes have been freshened by desiccation, in the sediments that underlie them; this, however, as our studies have shown, is not the case. It does not appear, therefore, that the geological condition of the ancient lake basins in which thinolite occurs bears out the suggestion derived from the crystallographic study of the pseudomorph. What the composition of the original mineral may have been still remains undetermined.

The relation of thinolite to the "barley corn" pseudomorph found near Sangerhausen, in Thuringia, is pointed out by Dana, and also the fact that similar crystals have been obtained in other parts of the world. Some of the specimens from the various foreign localities, apparently identical with the mineral we are studying, are represented on Pl. XXVI. So far as known none of the specimens from localities outside of the Lahontan and Mono basins were deposited in lakes; the conditions under which they were formed must

therefore differ widely from those that prevailed in the Quaternary lakes of the Far West.

No chemical precipitates excepting calcium carbonate are known to have been formed in the ancient lake of Mono Valley, and we have no information further than that afforded by the chemistry of the waters of the present lake to indicate that evaporation to dryness ever took place. The present lake contains approximately 5 per cent. of total solids in solution; it is therefore far from being a saturated brine, and is certainly not a mother liquor from which various salts have been crystallized.

The chemical composition of the lake shows that it has not been subject to concentration for a great length of time. A quantitative measure of the period necessary for the present degree of concentration to be attained can not be reached, as the composition of the inflowing waters and the rate of evaporation from the lake surface are not known. Whether the lake has held its integrity or not since the commencement of the Quaternary remains to be determined. Its salts have not been flooded out by overflow, and if they are less than would have been contributed by the streams and springs since the ancient beaches were formed, then the only conclusion to be drawn is that freshening by desiccation has taken place. If this process had occurred we should expect that the bottom of the lake would be a level plain formed of playa deposits, which as our soundings indicate, is not the case. Owing to the orographic disturbances, however, and the formation of craters in the center of the lake, from which considerable quantities of lapilli and lava have been recently thrown out, the original contour of the basin has been destroyed. The evidence from this quarter bearing on the question of desiccation thus becomes nil.

The process of the freshening of lakes by desiccation, as determined in the Lahontan basin, is thought to have taken place in Mono Valley as well, but the evidence in hand is not sufficient to completely sustain the hypothesis. This supposition finds some support, however, when the histories of Mono and Owen's Lakes are compared. These two water bodies have a very similar environment, and are quite similar in chemical composition, as is shown by the analyses in Table A. Owen's Lake, as reported by G. K. Gilbert, overflowed during the Quaternary; its present density must, therefore, have resulted from subsequent concentration. As Mono Lake contains one per cent. less of total solids in solution than its sister lake, it is apparent that it too must have undergone some recent change by which its salts were eliminated.

It might be suggested that the lake had been freshened at some period in its history by the escape of its waters through underground passages. Such an event is certainly possible, but no facts are known which indicate that it ever took place.

FOSSILS.

Lake Mono, as has already been stated, is destitute of molluscan and piscine life. It is inhabited only by a crustacean peculiar to alkaline and saline waters and by insects and their larvæ. We should perhaps qualify this statement, as the lake has not been studied by naturalists and may yield a more abundant fauna than we have stated when carefully examined. So far as indicated by the fossils derived from the sediments exposed in the basin, the Quaternary lake was as destitute of molluscan and higher forms of life as is the present. The only fossils found in the lacustral sediments, besides diatoms and other microscopic organisms, are the cases of a minute ostracoid crustacean of the genus Cypris. At the bottom of a well about one hundred feet deep, on the northern margin of Mono Valley, near the southern end of Trench Cañon, the shells of three species of fresh water mollusks were obtained. The gravels containing these shells are water worn and appear to belong to an ancient beach, thus indicating (the evidence from these fossils alone being by no means decisive) that the former lake, during its higher stages, was fresh.

The profusion of diatoms in the sediments of the ancient lake assures us that the conditions at the time the sediments containing them were deposited must have been exceedingly favorable for the development of this form of life. Some of the beds on Paoha Island, throughout a thickness of twenty or thirty feet, are almost entirely composed of the siliceous cases of these microscopic organisms. A systematic study of the diatoms and protozoans inhabiting the present lake and of the remains of similar forms of life contained in the ancient sediments of the same basin would no doubt be fruitful of interesting results. Up to the present time such an investigation has not been undertaken.

EXPLANATION OF PLATE XXVI.

THINOLITE CRYSTALS.

FIGS. 1 and 2. Thinolite from Lake Mono, California (natural size), showing the grouping of the composite crystals.

FIG. 3. Thinolite from Lake Mono (natural size), fragment of a large composite crystal, made up of small acicular crystals in parallel position.

FIG. 4. Transverse section of the crystal represented in Fig. 3, showing the same skeleton structure distinct in crystals, deposited in Lake Lahontan, from Pyramid Lake, Nevada. (Figs. 14, 15, etc.)

FIGS. 5 and 6. Group of thinolite crystals from Lake Mono (natural size), showing the acicular form, and also the way in which the crystals are coated over with secondary carbonate.

FIG. 7. Group of small crystals (magnified 4 times) from Lake Mono, showing the same method of grouping common in the Sangerhausen pseudomorphs, as shown in Fig. 8.

FIG. 8. Group of Sangerhausen pseudomorphs (natural size): compare Fig. 7.

FIG. 9. Isolated thinolite crystals, deposited in Lake Lahontan (magnified twice), showing resemblance in form and surface mark ng to Sangerhausen crystals; compare with Fig. 12.

FIG. 10. Thinolite crystal (natural size), showing cap-in-cap pyramidal structure, similar to Figs. 27 and 28 (deposited in Lake Lahontan).

FIG. 11. Thinolite crystal (magnified 4 times), showing resemblance in form to the Sangerhausen pseudomorphs; compare with Fig. 12 (deposited in Lake Lahontan).

FIG. 12. Single Sangerhausen crystal, showing form and external markings (magnified twice).

FIG. 13. Group of small thinolite crystals deposited in Lake Lahontan (magnified 4 times); compare with Fig. 8.

FIGS. 14 and 15. Transverse sections (natural size), deposited in Lake Lahontan; Fig. 14, open skeleton form; Fig. 15, partially filled up with amorphous $CaCO_3$. These sections show the system of rectangular (square) and diagonal ribs, which consist of granular crystalline $CaCO_3$.

FIG. 16. External appearance (reduced one-half) of a single crystal deposited in Lake Lahontan, with part of a second, the internal structure of which shows that it has but a single termination; the comparatively smooth surface is due to the secondary deposition of $CaCO_3$.

FIG. 17. Longitudinal section of open variety (reduced one-half), showing the two systems of plates converging upward at an angle of about 35° (deposited in Lake Lahontan).

FIG. 18. Acute pyramidal crystal (reduced one-half) which yielded at its base the section given in Fig. 15 (deposited in Lake Lahontan).

FIG. 19. Square pyramidal crystal (reduced one half) which gave, at the point indicated, the section in Fig. 24; the surface has been made smooth by subsequent deposition of $CaCO_3$ (deposited in Lake Lahontan).

FIGS. 20 and 21. Skeleton crystals (natural size) showing cap-in-cap structure, and thus revealing the true square pyramidal form of the original mineral (deposited in Lake Lahontan).

FIG. 22. Crystals (natural size) from the Domes, Pyramid Lake; the surf ce smoothed over by subsequent depositions of $CaCO_3$, with sproutings from the edges and extremities.

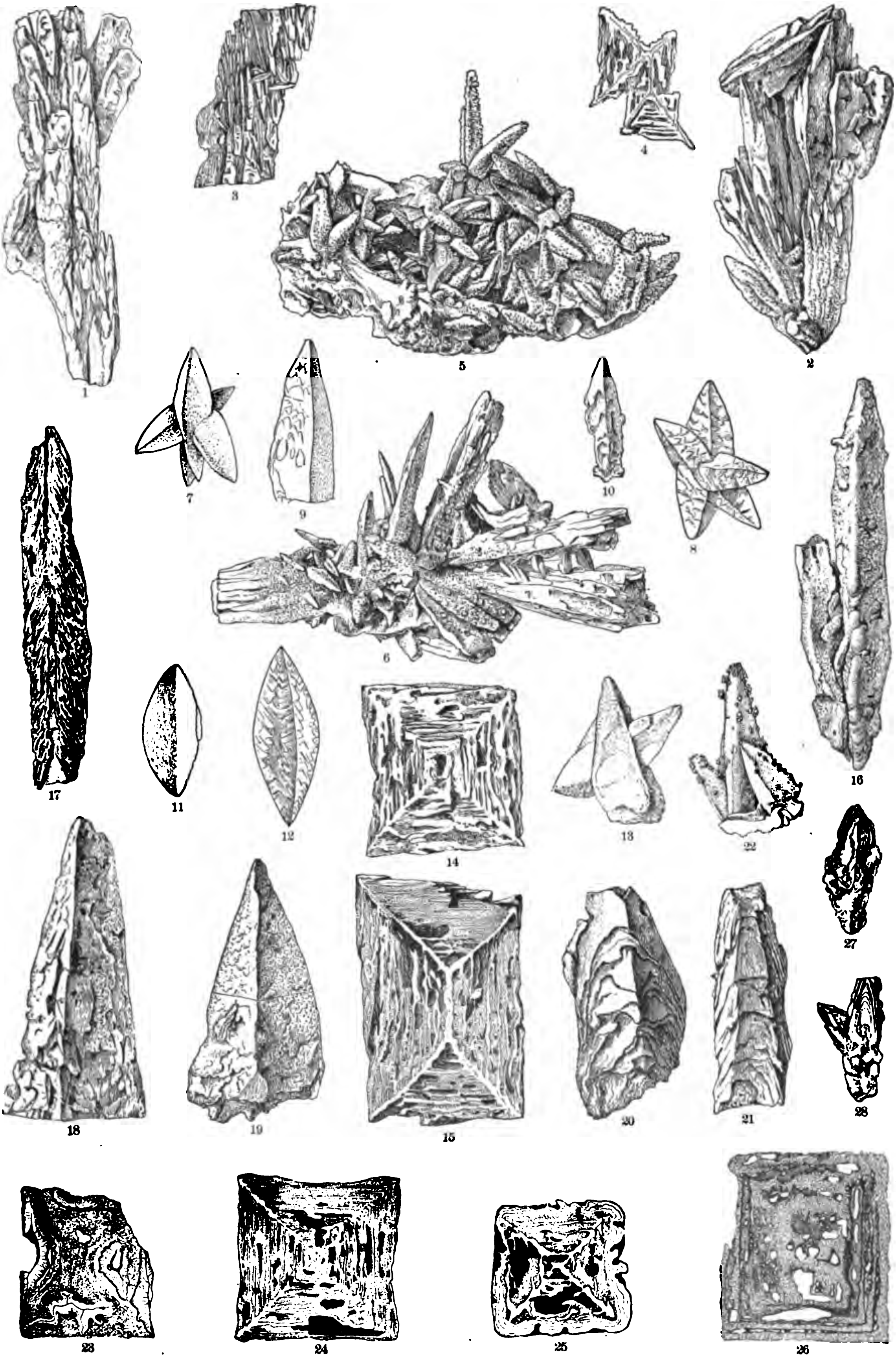
FIG. 23. Section (magnified 8 times) of a crystal from the Domes, like that in Fig. 22, showing a diagonal and rectangular frame-work, partly crystalline, granular, partly amorphous, with layers of secondary carbonate opal-like in structure.

FIG. 24. Section (natural size) of the crystal shown in Fig. 19, cut transversely at point indicated; it shows the same framework of granular crystalline carbonate, partially filled in with secondary CaCO.

FIG. 25. Section (natural size) showing the usual frame-work, partially filled in with secondary $CaCO_3$, and with successive layers also around the outside (deposited in Lake Lahontan).

FIG. 26. Section of a crystal from the Marble Buttes, Nevada (magnified 8 times), and showing the structure lines of crystallized carbonate, and also in the cavities the acicular crystals of aragonite (?) (deposited in Lake Lahontan).

FIGS. 27 and 28. Small pyramidal crystals (natural size), showing by dissection the cap-in-cap structure, and thus, like Figs. 20 and 21, revealing the true pyramidal form of the original mineral (deposited in Lake Lahontan).



THINOLITE CRYSTALS.

GLACIAL HISTORY.

THE HIGH SIERRA.

The Sierra Nevada presents the topographic form of a monoclinal ridge of the Great Basin type. The eastern face of the range is precipitous and rugged, and its character and direction are determined throughout an extent of three or four hundred miles by an irregular and branching fault which has a throw of many thousand feet.

The western slope of the range is gentle in comparison with the eastern escarpment, and has been scored by deep, cañon-like valleys, which in several instances are from twenty to forty miles in length. The distance from the crest of the range to its eastern base is frequently not more than two or three miles; while the distance from the crest to the western base is generally more than twenty miles and in places exceeds forty miles. The range may be considered as an upheaved crest or monoclinal ridge, modified by the action of water and ice. The notches cut by erosion cause the serrate appearance of the range when seen from a distance. An observer standing on almost any one of the higher peaks of the Sierra will find that many points along the eastern margin of the tilted block from which the range has been sculptured rise to about the same height; thus indicating that the peaks have not been elevated separately, but that the intervening depressions have been excavated in a ridge which originally had a nearly uniform crest line. At many places of observation commanding a view along the western slope of the range, the furrows of erosion are hidden from view, while the ridges between appear to form a continuous and but slightly modified inclined plane, sloping westward at a low angle. Many other observations might be cited in illustration of the simplicity of the topographic plan of the Sierra Nevada, when erosion is not considered. In its essential features this magnificent mountain range agrees with the smaller basin ranges, but when its structure is studied in detail many disturbances and complications will no doubt appear which have not been recognized in the ranges to the eastward.

The crest line of the Sierra Nevada reaches its greatest elevation between latitudes 36° and 38°; its culminating point is Mt. Whitney, which rises 14,522 feet above the sea.[1] Southward from this peak the range declines rapidly and is considered as terminating at Tehachipi Pass, in latitude 35°. The northern terminus of the Sierra Nevada, as determined by J. S. Diller, is just south of Lassen Peak or in about latitude 40°.[2]

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[1] U. S. Signal Service, Professional Paper No. 15, p. 194.

[2] Notes on the Geology of Northern California, Bull. U. S. Geol. Survey, No. 33, p. 10.

North of Mt. Whitney there are many peaks that rise to an elevation of from ten to thirteen thousand feet, and are divided one from another by cañons and gorges which have been sunk thousands of feet in the mountain mass. This portion of the range is extremely rugged and has been named the High Sierra by the geologists of the California Survey. Its boundaries are indefinite, but it may be considered as embracing the more elevated portion of the Sierra Nevada between Tehachipi and Sonora Passes, or, in a more general way, between Owen's Lake and Lake Tahoe. The entire region bristles with rugged peaks and precipitous crests, overshadowing profound cañons and magnificent amphitheatres. There has been great erosion in nearly all portions of the range, but it has resulted in carving valleys and cañons rather than in a general degradation of the entire area. This is shown especially by tables and crests high in the range, which are bounded on all sides by precipices, but are covered with water-worn gravels that must have been deposited before the dissection of the mountains now in process began. These isolated gravel beds on the higher portions of its crest form, to the geologist, one of the most wonderful features of the High Sierra. They are the débris resulting from stream erosion which took place before the mountains had their present elevation. A portion of one of these areas is shown on the right hand slope of the peak forming the center of Pl. XXX. The positions of other similar areas may be distinguished on the accompanying map (Pl. XVII). One of the largest occurs on the table land north of Mt. Dana; four other similar fragments surround the immense amphitheater in which Silver Creek rises. The age of these gravels has not been definitely ascertained, but they are probably outliers of the great series known as the auriferous gravels, which occur principally on the western slope of the range. Whether these elevated patches are gold-bearing or not has never been tested, so far as the writer is aware.

The cañons carved in the upheaved mountain mass are mainly the work of streams flowing away from the crest of the range; or, more technically, the drainage is consequent to the present topography. Some great trenches, however, of which Bloody Cañon is the best example, ascend one side of the range, cross the summit, and descend the opposite declivity. In these instances the sharp divide that formerly separated the water-cut cañons on opposite sides of the crest may have been removed by glacial erosion, or the cross trenches may be remnants of old drainage channels existing before the Sierra was elevated above the adjacent region.

The peaks of the High Sierra present two well-marked types. Many, especially on the crest of the range, are extremely precipitous on one side and have a comparatively gentle slope in other directions. An example of this form is furnished by Mt. Dana, the northern face of which is a precipice a thousand feet high, while the

southern slope is quite moderate, as shown by the profile of the mountain when seen from the west.

Other peaks, situated principally in the central portion of the range, have the form so characteristic of many Alpine mountains, and are composed of a number of narrow crests, or "arêtes," as they are called in Switzerland, which meet at the summit. Between these narrow ridges are deep amphitheaters or cirques, which were formerly the sources of magnificent ice rivers, and now contain miniature glaciers. Fine types of this characteristic mountain form are furnished by Mt. McClure, where four long narrow crests meet at the culminating point, and by Mt. Ritter, which is formed by the union of five narrow crests.[1]

The similarity between the topography of many of the higher peaks of the Sierra Nevada and the "aiguilles" of Savoy will be appreciated by all who are familiar with the mountains of California and the grand scenery about Chamouni. In fact, the High Sierra presents many features that would be found to be characteristic of the Alps if their glaciers and snow fields were removed.

As a mental picture of the Sierra Nevada, we have an immense, irregular table land, upraised along its eastern edge so as to have a gentle western slope, but presenting a bold serrate face to the observer from the desert valleys skirting its eastern base. The elevated mass has been carved by erosion into a wonderful labyrinth of cañons and amphitheaters and ground down by glaciers until only detached fragments of the original surface remain. The dissection of the mountain mass has been produced by the combined action of water and ice. There are consequently two types of topography superimposed on each other or blended one with the other.

The result of this double process of upheaval and denudation is a magnificent mountain range, which is alike fascinating to the traveler, to the geologist, and to the artist. To California it has brought not only a lavish supply of useful and rare metals, but it has given her a climate of unusual salubrity and water with which to irrigate the wheat fields of her great valley. When the full grandeur of the High Sierra shall become known to the world—or even, we might say, to the people who live within sight of its snow-crowned summits—a new source of wealth will be added to California's already abundant resources in the same manner as the prosperity of Switzerland has been promoted by the fame of her mountains.

It is not necessary to devote special attention to the topography of this portion of the basin as the various features in which we are specially interested will receive attention as we proceed. Moreover, the topography of the High Sierra has already been described by explorers who are more familiar than I am with its details, and who

[1] Since these pages were written an instructive discussion of the drainage systems of the Sierra Nevada has been published by Joseph Le Conte in the American Journal of Science, 3d series, vol. 32, 1886, pp. 167–181.

have had far better opportunities to study the manner of its origin. I refer especially to the work of J. D. Whitney and his assistants on the Geological Survey of California.

The descriptions of the High Sierra from the pens of various writers which are scattered through scientific journals and literary magazines are too numerous to catalogue here; I can refer only to a few of the more important reports that have appeared.

The Auriferous Gravels of the Sierra Nevada of California, by J. D. Whitney, and The Climatic Changes of Later Geological Times, by the same author, should be familiar to all students of the geology of the High Sierra. Much information will be found in the reports of the Geological Survey of California, Geology, vol. 1, 1865, and in the various editions of the Yosemite Guide Book, published by the same Survey. Clarence King's attractive book on Mountaineering in the Sierra Nevada should also be in the hands of all who are interested in the scenery or the geology of this region.

EXISTING GLACIERS.

A summary of what is known concerning the living glaciers of the Sierra Nevada may be found in an essay on the existing glaciers of the United States, in the Fifth Annual Report of the U. S. Geological Survey. The following sketch of the present condition of the mountains forming the southwestern border of the Mono Basin contains no new observations relative to the ice bodies now existing about the higher peaks, but is intended simply as a brief introduction to the Quaternary glacial history of the region.

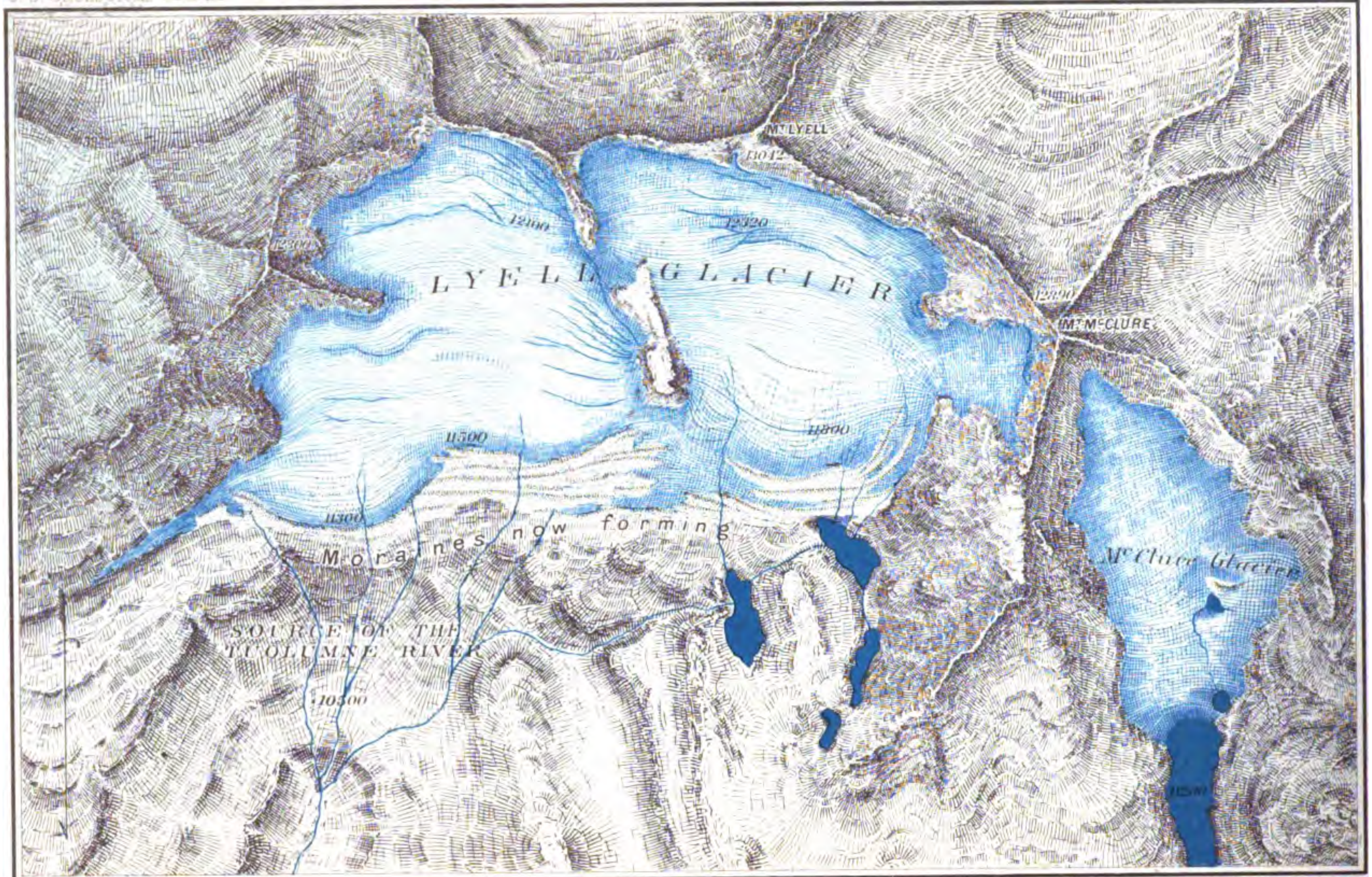
The present ice bodies of the sierra are small and but miniature counterparts of the glaciers found in many other regions. They occur mostly in deep cirques on the north sides of the more lofty peaks, and, with few exceptions, flow northward. Observations made during the survey of Mono basin show that there are nine small glaciers within the area draining into Mono Lake. Five of these occur along the lofty crest connecting Mt. Ritter and Mt. Lyell; another is found at the head of Parker Creek; one of the smallest in the basin occurs on the northern slope of Mt. Gibbs; while one of the most interesting nestles at the foot of the steep northern face of Mt. Dana; still another, larger than the Mt. Dana glacier, may be seen on the precipitous northern slope of Mt. Conness.[1]

As types of these ice bodies we shall briefly describe three that were specially examined and insert a few illustrations previously issued in the Fifth Annual Report referred to above.

MT. DANA GLACIER.

At the base of the northern face of Mt. Dana there is a deep gorge, called Glacier Cañon on the accompanying map, which drains north-

[1] The propriety of considering these small ice bodies true glaciers has recently been questioned by S. F. Emmons. Proc. Colorado Scientific Soc. vol. 2, pt. 3, 1887, pp. 211-227.



W.D. Johnson, Topographer.
I.C. Russell, Geologist.

M^T LYELL GLACIER.
Scale 3¾ inches = 1 mile.

ward into Leevining Creek. At the head of this gorge is a small cirque in which a miniature glacier is cradled. This ice body is about half a mile long, with a somewhat greater width, but, in spite of its small size, it has all the characteristic features of greater glaciers. It is composed of compact banded ice, is crossed by crevasses and dirt bands, is divided into névé region and glacier proper, and has bowlders and rock débris scattered over its lower margin. About the foot of the ice there is a typical, crescent-shaped, terminal moraine, in which scratched and battered stones are common. Thus, in all its features, this ice body, which we have called the Mt. Dana glacier, agrees with the principal characteristics of the great ice rivers found in other regions.

MT. LYELL GLACIER.

At the head of Tuolumne Cañon, on the north side of Mt. Lyell, is the largest glacier in the neighborhood of Lake Mono. A map of this glacier forms Pl. XXVII, which, together with the accompanying view (Pl. XXVIII), will obviate the necessity of a lengthened description. The moraines now forming about the foot of the glacier appear in both illustrations, and on the map the principal crevasses are shown by irregular blue lines.

PARKER CREEK GLACIER.

The Parker Creek glacier is situated at the head of the deep, high grade cañon through which Parker Creek descends to the valley of Lake Mono. It is smaller than the ice bodies on Mt. Dana and Mt. Lyell, yet it is a true glacier, with well-defined névé region, from beneath which descends a mass of ice that is crossed by dirt bands and crevasses and has many of the minor features characteristic of glaciers. About the foot of the ice there are moraines, forming concentric ridges, which in mass must far exceed the glacier as it exists at the present time. These moraines are more characteristic examples of the tumultuous débris piles formed by ice action than any other recent deposits of the same nature seen by the writer in the High Sierra. Like the majority of glaciers in this region, the one at the head of Parker Creek is sheltered from the sun by the lofty walls of an amphitheater and flows northward. The melting of this glacier gives origin to a small stream of turbid water which deposits an extremely fine light-colored mud in the pools formed when its course is obstructed.

The other glaciers in the Mono basin are of the same character as those we have briefly noticed and need not receive special attention at this time.

Each of the ice bodies observed occurs at the head of a deep cañon which was once filled by a magnificent trunk glacier. The largest of these ancient glaciers originated in the amphitheater on the side of Mt. Lyell, and flowed down Tuolumne Cañon, forming a veritable

river of ice over two thousand feet deep near its source and about forty miles long.

The present glaciers are perhaps the shrunken remnants of the ancient ice rivers; but, if we follow the teachings of Lake Lahontan, we must conclude that, like the present desert lakes to the east of the Sierra Nevada, they have had a fresh beginning within quite recent times. The Quaternary glaciers of the Sierra may reasonably be supposed to have passed away completely during the arid period which followed the last high water stage of Lake Lahontan. The present glaciers are therefore the result of a modern climatic oscillation, but whether they mark the commencement of a secular period of low mean annual temperature or not remains for future observers to decide.

In the essay on the existing glaciers of the United States, already cited, a somewhat detailed description is given of the various glacial phenomena observed in the High Sierra. This includes observations concerning moraines, crevasses, dirt bands, lamination, perched blocks, ice pinnacles, glacier tables, etc., comprehending in fact all the phenomena that may be seen on larger glaciers. It does not seem necessary to repeat here the descriptions of phenomena already recorded.

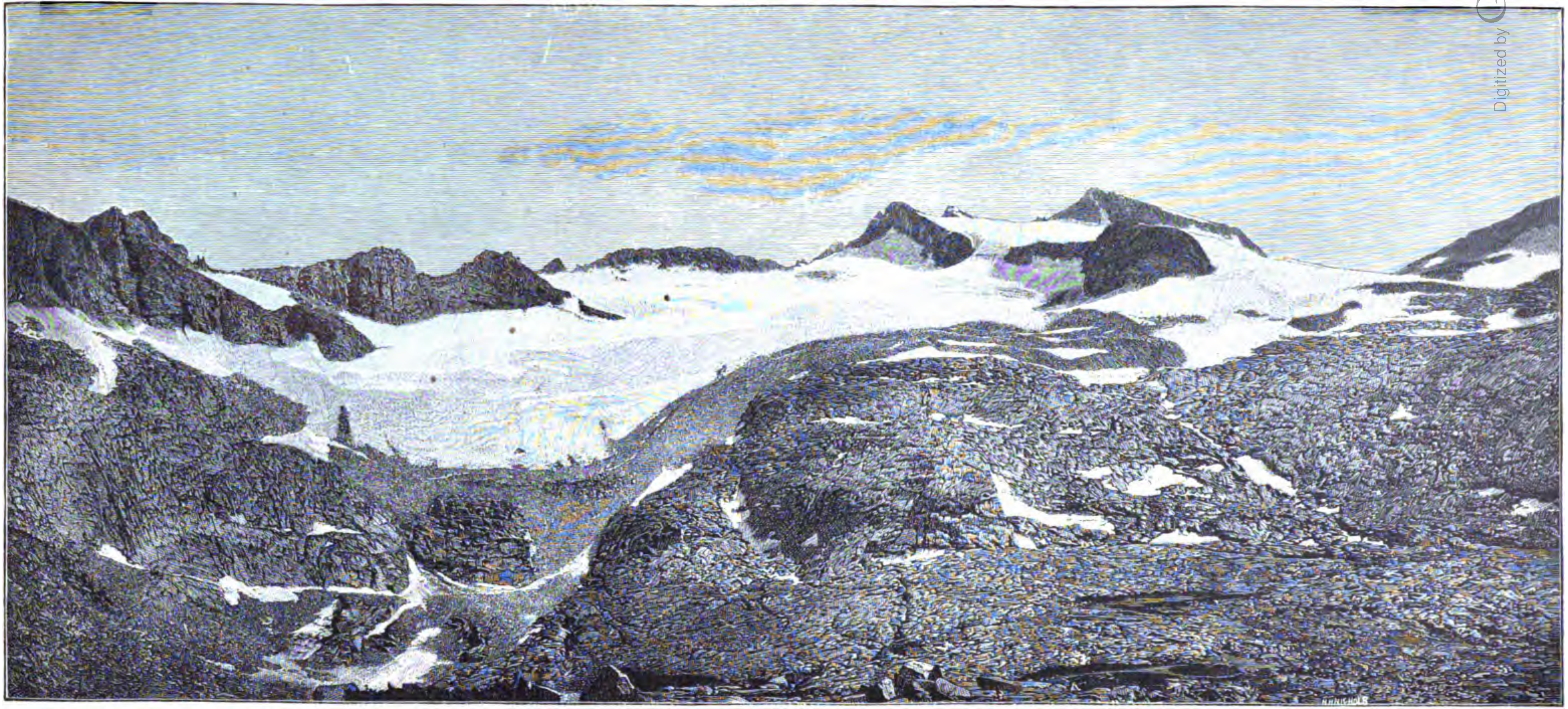
QUATERNARY GLACIERS OF THE HIGH SIERRA.

The fact that the Sierra Nevada bears the records of having formerly been the source of immense glaciers has been recognized by all geologists who have visited the region, but no systematic study of the glacial phenomena displayed throughout a large portion of the range has been carried out. An arduous task, but one of fascinating interest, here awaits the geological explorer.

The labors of the geologists of the California Survey have shown that glaciers of great magnitude formerly existed on the high peaks about which Kern and King Rivers rise.[1]. Here are the most southern glacial records that have been reported in the Sierra Nevada, but the extreme southern limit of the glaciated region has not been definitely determined. Judging from the topography of the southern portion of the range and the average elevation of the ancient glaciers in the adjacent mountains, it seems evident that they could not have extended far to the south of Mt. Whitney.

No special examination of the glacial records in the extremely rugged region between Mt. Brewer and Mt. Ritter has been made, but a view of these mountains from the summit of Mt. Lyell assured the writer that many of the peaks in this mountain mass have glacial cirques about their summits and that all the larger cañons which separate them were once occupied by ice rivers.

[1] Geol. Survey California, Geology, vol. 1, 1865, pp. 372–378.



MOUNT LYELL GLACIER.
From a photograph.

The character and extent of the glaciers which formerly occupied the San Joaquin, Merced, and Tuolumne Valleys have been described by several observers.[1] In the following pages, it is hoped that something will be added to what has already been reported concerning these and other glaciers in the same region.

Continuing northward, glacial records have been observed about Silver Mountain and at Sonora Pass, which crosses the range midway between lakes Mono and Tahoe.[2]

About the southern border of Lake Tahoe magnificent moraines of the same type as those that descend to the plain in the Mono basin have been studied by Joseph Le Conte. Glaciers also existed about the northern border of the lake, as well as in the cañon which leads from it.[3] Northward of Lake Tahoe the beds of local glaciers which delivered their drainage into Washoe Valley have been examined by the writer. The traveler over the Central Pacific Railroad may observe ancient moraines in the vicinity of Donner Lake. How far north of the railroad similar records may be found is not definitely known, but the limit of the glaciers in this direction is thought to have been in the moderately elevated country south of the head waters of Feather River. In crossing the range by the most direct route between Honey Lake Valley and Red Bluff, the writer failed to observe any evidence of glaciation. The mountains in this region are comparatively low and are believed to have been below the horizon of the glaciated zone so strongly marked farther south.

It is well known that Lassen Peak, Mt. Shasta, and many of the monarchs of the Cascade Range were glacier-crowned during the Quaternary, but each of these mountains was an independent center of accumulation from which local systems of glaciers radiated.

Besides these individual peaks about which the larger glaciers clustered, there must have been, judging from the observations of J. S. Newberry, C. E. Dutton and others, a general névé covering all the higher portions of the Cascade Range, similar to the ancient snow fields of the Sierra Nevada.

The reports cited in the preceding pages, together with observations of the writer, are sufficient to show that the Sierra Nevada during the glacial epoch was covered by an immense névé field, which probably stretched continuously from a little north of latitude 36° nearly to latitude 40°. The width of this belt of perpetual snow must have been irregular, conforming to the present topography of

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[1] Geol. Survey California, Geology, vol. 1, 1865, pp. 364–450. Geol. Survey California, Yosemite Guide Book, Chap. IV, 1868. (See also other editions.) Joseph Le Conte. in Proc. California Acad. Sci., vol. 4, 1872, pp. 259–262; Am. Jour. Sci., 3d series, vol. 5, 1873, pp. 325–342; ibid., vol. 10, 1875, pp. 126–139; ibid., vol. 18, 1879, pp. 35–44.

[2] Geol. Survey California, Geology, vol. 1, 1865, pp. 440–442.

[3] Am. Jour. Sci., 3d series, vol. 10, 1875, pp. 126–139.

the summit of the range, but it probably had an average width of between ten and fifteen miles. From beneath this snowy mantle trunk glaciers flowed both east and west down the flanks of the range.

The evidence is such as abundantly to justify the conclusion that the ancient glacial system of the Sierra Nevada was local and had no connection with a northern ice sheet. The glaciers were clustered about and radiated from the higher portion of the range in the same manner as from the contemporary névé fields of the Wasatch and Uinta Mountains, a map of which has been published by the geologists of the 40th parallel exploration.[1]

Nothing is more definite in the Quaternary geology of the Far West than that the desert country south of central Oregon was never buried beneath a great mer de glace like that which formerly extended over Canada and the New England States. The northern limit of this unglaciated region has not been determined.

When we speak of the Sierra Nevada as having been covered by a long, narrow névé field, it is not to be understood that the entire crest of the range was buried beneath solid ice in such a manner as to increase its height and completely conceal the rocky summits. On the contrary, many of the peaks and lofty crests were not covered with continuous snow. Where the névé was thickest it became consolidated into glacier ice, which filled all the higher valleys and amphitheaters and formed reservoirs for the supply of the ice-streams that flowed from it in various directions. These slow moving ice-rivers cleared the previously formed stream-valleys of their accumulated débris and remodeled their forms to a considerable extent. On the advent of a more genial climate the drainage channels were once more surrendered to the streams, without profound modification of the preglacial topography. The higher portions of the range outside the cañons occupied by the trunk glaciers were abraded and rounded over large areas by what may be considered as névé movement, in distinction from the work of the more definite ice-streams. The higher spires and the arêtes which unite to form the Alpine peaks are mostly without glacial records and must have risen above the surface of the névé. The same is true of the gravel plateaus I have mentioned as occurring in the High Sierra south of Lake Mono.

The character of the ancient glaciers of the Sierra is illustrated on a comparatively small scale by the existing glaciers of Switzerland. The névé region of the Mer de Glace, as represented on the map accompanying J. D. Forbes's well known book of travel through the Alps of Savoy, illustrates what must have been the general aspect of the High Sierra during the glacial epoch.

The records of the ancient glaciation consist of a general round-

[1] Reports U. S. Geol. Expl., 40th Par., 1876, Systematic Geology, vol. 1, map 5, p. 486.

W. D. Johnson, Topographer

I. C. Russell, Geologist.

THE MONO BASIN IN QUATERNARY TIME.

Scale 1: 250 000.

5 0 5 10 15 20 miles

Contour interval 200 feet – datum mean sea level.


Walker River
Robinson Creek Glacier
Green Creek Glacier
Virginia Creek Glacier
DUNDERBURG PK.
DUNDERBURG BASIN
Lundy Cañon Glacier
CEDAR HILL
LAKE MONO (QUATERNARY.)
7060 feet above sea level - Maximum depth 828 feet.
HYDROGRAPHIC BASIN

ing and abrasion of the surface over large areas about the more elevated portions of the range, the formation of cirques or amphitheaters on the sides of the peaks and crests, the removal of soil and débris from the surface, the broadening and rounding of cañon bottoms, the deposition of lateral moraines along the sides of valleys, the formation of morainal embankments where trunk glaciers left the narrow gorges and were prolonged upon a plain, scratched and polished surfaces, perched blocks, etc.

From evidence of this character one is enabled to map the general area occupied by the névé fields of the Sierra Nevada and to trace the paths followed by the ice-streams as they flowed away from the perpetual snow about the mountain tops. This work has progressed far enough to show that glaciers occupied many if not all the higher valleys and sometimes attained a length of thirty or forty miles. We also learn from the records, as has been previously mentioned, that the glacial epoch was broken by intervals of comparatively warm temperature, during which the extremities of the glaciers retreated up the cañons. How great the melting of the ice may have been during the interglacial periods has not been determined. We know, also, that when the glaciers finally retreated their recession was slow and marked by many pauses, during which small terminal moraines were formed.

The facts on which these conclusions rest, as well as many minor features in the history of the ancient ice-streams, will appear in the descriptions of the glacial records of the Mono basin which follow.

NÉVÉ REGION AND QUATERNARY GLACIERS OF THE MONO BASIN.

Much of the area above the region occupied by the main Quaternary glaciers in the mountains south of Lake Mono is characterized by rounded contours and flowing outlines, due to a general abrasion of the surface by the mantle of snow and ice which once moved over it in various directions. The upper limit of this region can not be traced with accuracy, as it has no definite boundary. Its lower margin is also uncertain, for the reason that it merges by insensible gradations with the areas formerly occupied by definite ice-streams. The outlines of the area of general ice erosion can not be assigned to any particular glacier, but was occupied by the ice and snow from which the various ice-streams originated. This névé region and the glaciers that flowed from it is indicated on the accompanying map (Pl. XXIX) as accurately as its character will admit.

These ancient névés covered all the elevated portions of the Sierra Nevada, excepting the dominant peaks and the more abrupt crests, and filled all the Alpine valleys with snow and ice, in some cases to the depth of between one and two thousand feet. The topography of the mountains enables one to determine that there were two principal regions of this character within the hydrographic basin of

Lake Mono. One of these embraced the deep north-and-south valley at the southern base of Mt. Dana and was the source of five glaciers of large size. I have named this the Mt. Dana névé field. It embraces the Dana and Conness basins, shown on the map. Another filled the elevated basin now drained by Rush Creek and was bounded for four-fifths of its periphery by the Great Basin-Pacific divide. This includes a portion of the Ritter basin, shown on the map, and may be designated the Rush Creek névé field.

MT. DANA NÉVÉ FIELD.

The Mt. Dana névé field was so deeply filled with ice and snow during the glacial epoch that the divide between the eastern and western drainages of the mountains must have been shifted to the west of its present position, and was probably indefinite and variable throughout the existence of the glaciers. A part of the ice which flowed through the channels leading to Mono Valley was formed from the snow which fell to the west of the present divide. This will be understood more clearly by referring to the map of the region. The divide in the bottom of the valley at the head of Bloody Cañon and the divide at the commencement of the Leevining Creek drainage are determined by very small changes of contour. Were the upper portions of these cañons deeply filled with ice it is evident that the divide between the waters flowing into the Great Basin and those which found their way into the Pacific would not have its present position.

The névé field to the south of Mt. Dana was in reality a glacier in its lower strata and modified its bed in the same manner as did the trunk glaciers originating from it. It received tributary ice-streams from the north side of Mt. Conness; from Glacier Cañon on the north side of Mt. Dana; from Dana Creek Cañon, between Mt. Dana and Mt. Gibbs; and from a number of cirques on the north side of the Kuna crest. The ice-body supplied from these various sources and from the snows that fell on its surface was about fifteen miles long from northeast to southwest and had an average breadth of approximately three miles. On the west it became confluent with the great Tuolumne glacier through the valley of Dana Creek. A portion of the bed of this ice-body is shown in middle distance on Pl. XV. The dominant peak in the picture is Mt. Dana, to the left of which is Glacier Cañon; in the background to the right is a portion of the Kuna crest, a lofty ridge of granite, with a number of deep amphitheaters sculptured in its rugged face.

In addition to the great glacier which flowed down Dana Creek Valley and formed one of the main tributaries of the Tuolumne Valley glacier, the Mt. Dana névé field was the source of four trunk glaciers which flowed eastward into Mono Valley. These were the Lundy Cañon, Leevining Creek, Bloody Cañon, and Parker Cañon glaciers.

MOUNT DANA, FROM THE WEST.

From a photograph.

RUSH CREEK NÉVÉ FIELD.

The drainage of Rush Creek and the drainage of Tuolumne River are now divided by a comparatively low crest, which runs northeast from Mt. Lyell and joins the southern end of the bold Kuna crest. The ancient snow fields of the Rush Creek and Tuolumne glaciers were confluent and ground down and abraded the divide now separating the waters of these drainage areas. At the time the glaciers had their greatest extension the ice may have flowed from either direction across the present divide. Considering, however, that the ancient névé had the same limits as the present drainage basins, it is evident from the topography that the Rush Creek névé occupied the extremely rugged but deeply eroded basin now draining into Rush Creek. The area of this névé field was approximately twenty-four square miles, a part of which is included in the great amphitheater in which Silver Creek rises. The huge, horse-shoe-shaped glacier of the lower part of Rush Creek received the greater part of its ice from the névé we have described, but yet had some tribute from two independent amphitheaters situated to the south of the great curve; each of these now holds a small lake. The highest portion of the Rush Creek névé was on the side of Mt. Lyell; this mountain was also the head of the glaciers which flowed down the Tuolumne and Merced Valleys. South of the Rush Creek névé field the ancient ice drainage was into the San Joaquin Valley.

On the map forming Pl. XXIX still another series of moraines is shown to the northwest of Lake Mono, which were deposited by glaciers originating about Dunderberg Peak and the elevated region to the west of it and descending into Bridgeport Valley. The snow fields drained by these glaciers are not included in the Mono basin and are mostly without the area represented on the accompanying map; they will therefore not receive attention at the present time. The ancient glaciers in this portion of the High Sierra were of the same type as those of the Mono basin.

Beginning at Lundy Cañon, we shall describe the trunk glaciers which drained the Mt. Dana and the Rush Creek névé fields in the order of their succession, proceeding from north to south.

LUNDY CAÑON GLACIER.

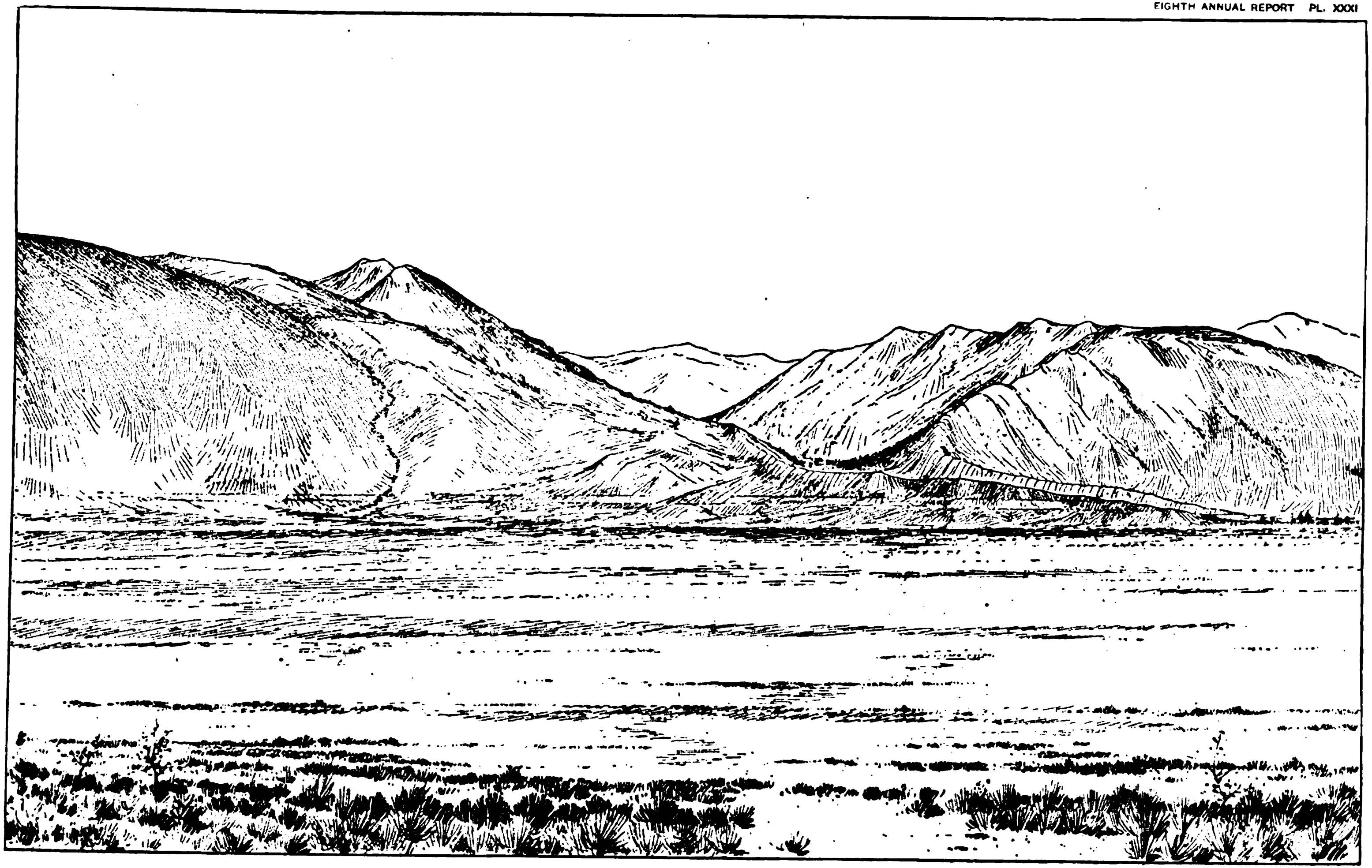
The ancient glacier of Lundy Cañon was supplied principally by the snows that fell on the north side of Mt. Conness; but, as it was one of the channels of overflow of the Mt. Dana névé field, it also drained a large portion of the region in the vicinity of Saddlebag Lake. This glacier received but little if any additions from the northern slope of the cañon through which it flowed, as the rocks were there too steep to retain the snow. Its main tributary was a glacier of considerable size which occupied Lake Cañon. The Lundy Cañon glacier was between six and seven miles long, with a general

width of approximately two thousand feet. At the mouth of Lake Cañon it was one thousand feet deep, and at the end of Lundy Cañon its thickness was about half this amount. During its greatest extension it emerged from the mouth of the gorge through which it flowed and was prolonged about half a mile into Mono Valley. Its highest limit on each side of the trough it occupied is recorded by lateral moraines. These are well defined near their lower limit, but can scarcely be distinguished in the higher and steeper portions of the cañon. At the mouth of the cañon the ancient glacier built parallel morainal embankments which still remain as fresh as if they had been formed but a few years. During the greatest extension of the ice the end of the glacier was below the horizon of the highest of the beach lines made by the ancient lake of Mono Valley. This is shown by the terraces carved on the moraines by the waves of the former lake. These special features of the various glacial records, however, will be described in groups after the main characteristics of the principal ice-streams are presented, thus avoiding repetition.

Lundy Cañon is to-day a broad-bottomed trench which extends with a low grade right into the heart of the mountains. On either side walls of granite and metamorphosed slates tower nearly perpendicularly to the height of between two and three thousand feet. The north wall of the cañon is unbroken, but on the south side a deep U-shaped notch marks the point where Lake Cañon becomes tributary to the main gorge. We have here one of the peculiar features of the glaciated valleys of the Mono basin. Both Lundy and Lake Cañons have a low grade, especially near their place of union, but the bottom of the main gorge is a thousand feet lower than the bottom of its tributary. The waters of Lake Çañon flow in cascades over solid rock to join the stream below. The character and the origin of high level tributary cañons of this nature will be considered on page 347, where other facts bearing on the subject are presented.

Lake Cañon is but three miles long and does not lead to a well defined peak or drain a former névé region. To the geologist this is one of the most peculiar cañons in the Mono basin, and one of the most difficult of the minor features of the region to account for. A view of nearly its entire extent, as seen from the divide at its head, is presented on Pl. XXXII. The cliffs forming the background of the picture are a portion of the western wall of Lundy Cañon. The débris piles occurring on either side of the gorge have been accumulated since the melting of the glacier. Similar steep half-cones of angular rocks, resulting from the atmospheric waste of the cliffs rising above them, are characteristic of Lundy Cañon and of other similar gorges of the region.

The bottom of Lundy Cañon, above the point where Lake Cañon joins it, is irregular and is formed of alternate scarps and terraces all the way to the head of the gorge, where a scarp of grander pro-



MORAINAL EMBANKMENT AT THE MOUTH OF LUNDY CAÑON.
From a photograph.

portions than those below crosses the trough and forms a wall of rock more than a thousand feet high. This rocky wall, together with the cliffs forming the eastern side of the gorge as far as Lake Cañon, has been named, in honor of the great French artist, the Doré Cliffs. On scaling this granite precipice one finds himself in the elevated valley once filled by the Mt. Dana névé field. Lundy Cañon presents another example of the terracing of glaciated valleys noticed in my introduction. The cliff at the head of the cañon must have caused a wonderfully grand cascade in the ice river which formerly flowed over it. From the foot of this fall to the mouth of Lake Cañon the ice must have been deeply fractured as it descended from terrace to terrace, and undoubtedly formed magnificent ice-pinnacles separated by deep crevasses. The observer, while endeavoring to restore, in fancy, the appearance of this gorge when occupied by glacial ice, may allow his imagination free scope without fear of overreaching the magnificence of the original.

LEEVINING CREEK GLACIER.

Leading south from the mouth of Lundy Creek there is a good road following the lake shore along the immediate base of the mountain mass which culminates in Mt. Warren. The shore is precipitous until the mouth of Leevining Creek is reached, where a low headland composed of gravel and sand projects into the lake. This is the delta of Leevining Creek and was mostly formed when the lake stood far above its present horizon. Like the one at the mouth of Lundy Creek, it starts between the extremities of morainal deposits that were accumulated previous to the highest water stage of the old lake. The creek cut a deep gorge through the delta as the lake fell, and at various pauses in the receding of the waters smaller deltas were begun in the gap cut through those previously formed. About two miles up this gorge the recently excavated stream-channel ends and the mouth of the glacial cañon begins. At this point a hill of débris crosses from side to side of the gorge, which is here quite narrow, and formerly dammed the great cañon that extends above. This is a terminal moraine, and, like the delta deposits below, has been cut through by the erosion of the present stream. From its bowlder-strewn crest one may obtain a fine view of the lower portion of the gorge of Leevining Creek, and can replace in fancy the immense ice-body that once filled the broad-bottomed trough through which the present stream meanders. As far as one can see up the cañon its bottom is nearly level, and its sides are smooth and even for about five hundred feet, to where the lateral moraines deposited on each border of the glacier mark the upper limit of the ancient ice flood. Above this limit, the rocks are rough and angular, illustrating the difference between ice and water erosion. At the point where the cañon bends to the west and is lost to view the northern wall is an

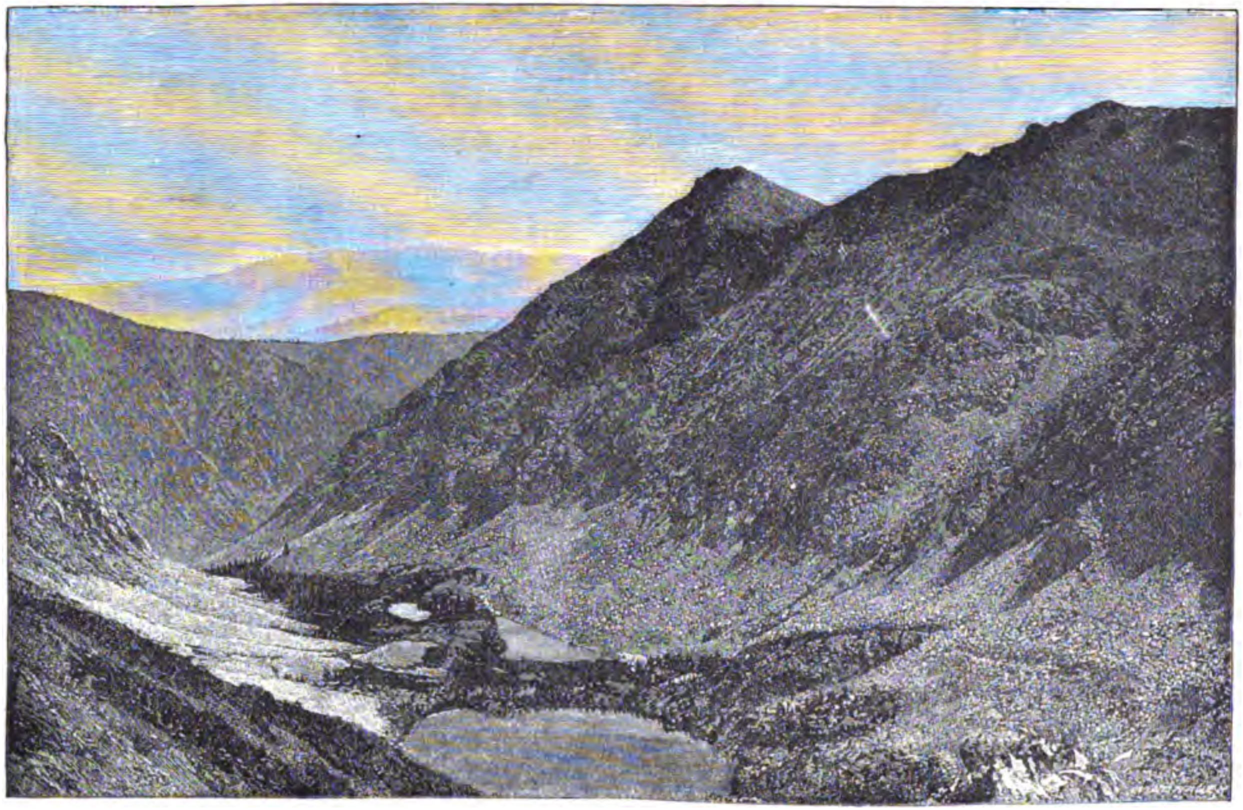
abrupt precipice, composed principally of quartzite and intrusive granite, which rises abruptly from the gorge with scarcely any talus slope at its base. On the opposite side the cliffs formed by the edge of the Dana plateau present a rugged curtain wall in which several small glacial cirques have been excavated. This is one of the grandest features in the scenery not only of Leevining Cañon but of the entire mountain region in the vicinity of Lake Mono.

If one proceeds up the cañon from the point of view mentioned above, he will cross five or six small terminal moraines which traverse from side to side the broad trench left by the ancient glacier. These are seldom more than fifteen or twenty feet high and are separated by grassy meadows. The creek was formerly dammed by these moraines and forced to expand so as to form small lakes; but these have long since been drained by the cutting of channels through the obstructions.

Above the last of the terminal moraines now distinguishable the cañon bends westward and, in its upper course, becomes so narrow that the talus slopes from either side meet in the center and fill the gorge with a confusion of angular rocks which render the ascent difficult even for an experienced climber. A view looking up this portion of the cañon is presented on Pl. XXXIII and illustrates the manner in which the glacial character of the trough has been nearly obliterated by the formation of modern talus slopes.

The cañon retains its low grade for a distance of about nine miles from its mouth and then ends suddenly in a steep scarp, which crosses the cañon with a precipitous, cliff-like face, a thousand feet high. Leevining Cañon thus corresponds with Lundy Cañon in its main features. It is a broad-bottomed, low-grade trench, leading directly into the mountains and terminating abruptly. The main or trunk portion of the Leevining Creek glacier is thus clearly defined by the "form" it has left. As shown by the topography, as well as by the glaciation of its bed and the moraines it left on melting, it is evident that this glacier drained the Mt. Dana névé field through two channels. One of these leads to the present site of Dana Lake. The other extended northward along the eastern base of Tioga crest and was divided at its head from the glacier of Lake Cañon by a narrow, rocky ridge. A branch of this northern arm also drained the Mt. Dana névé field through the gorge where Summit Lake is now situated. After the union of the two main trunks, the Leevining Creek glacier received a number of small tributaries from the cirques on the north face of the Dana plateau. Whether the Gibbs Cañon glacier became tributary to the much larger ice-stream of Leevining Cañon has not been determined with certainty, but during the height of the glacial epoch it may have furnished an important tributary.

The trunk glacier derived from the source we have indicated was between eight and nine miles long and had a remarkably uniform



LAKE CAÑON, LOOKING INTO LUNDY CAÑON.

From a photograph.

width of about three-quarters of a mile. The depth of the ice two miles from its terminus was about four hundred feet; near the first tributary from the face of the Dana plateau the glacier was nearly a thousand feet in thickness. For a long distance in the lower portion of the gorge the bottom of the glacier was about two thousand feet broad, while at the surface its width was, approximately, four thousand feet.

On the interior of the trough formed by the lateral moraines up stream from the lowest terminal moraine there is a terrace or ridge of débris which slopes down stream with a somewhat steeper grade than the crest of the moraine, and on approaching the terminal declines abruptly and joins it at either extremity. This inner crest and the terminal moraine with which it unites were formed at the same time and record the height and position of the contracted glacier at a definite stage in its retreat. Similar records of a shrunken glacier within the bed of a larger and older ice-stream may be observed in the Bloody Cañon, Parker Cañon, and Rush Creek moraines.

There is but little morainal material high up in Leevining Cañon, and modern talus-slopes have nearly obliterated the records of its former occupation by ice, but near its mouth, especially on the south side of the gorge, the deposits are of great size.

On the north side of the cañon, near its mouth, there is a morainal ridge on the steep side of the gorge, which has deflected the drainage from the slope above; but this ridge does not extend beyond the cañon's mouth and nothing of the nature of a morainal embankment is to be observed on the north side of the creek at the end of the gorge. On the south side, however, the lateral moraines are of great magnitude and form a free wall of débris between four and five hundred feet high, entirely separated from the true rock wall of the cañon. This is in reality a compound morainal embankment. A measured profile, drawn to the same vertical and horizontal scale through this part of the cañon, is shown in the following diagram.

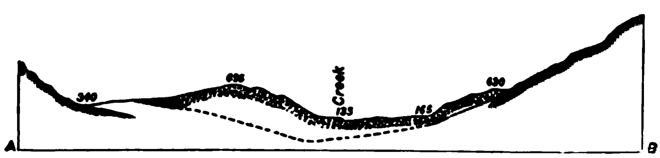


FIG. 3. Cross profile of Leevining Cañon morainal embankments. Vertical and horizontal scale: 1 inch = 3,000 feet.

The trough to the south of the main moraine was not occupied by ice, but was shut off by the right lateral moraine, which became the retaining wall of the glacier. Not only did the lateral moraine confine the glacier, but during successive stages secondary ridges were formed within those first deposited, so that the mass of débris, as we now find it, is compound and records at least four or five changes in the magnitude of the ancient ice-stream.

The remarkable manner in which this glacier adhered to the left or northern wall of the gorge through which it flowed will be reverted to when other phenomena of a similar character have been described.

The great magnitude of the right lateral moraines of the Leevining Creek glacier in comparison with those deposited along its left border, is due to the fact that the glacier received nearly all its tributary ice-streams from the south. Great quantities of débris must have been delivered to it by the small glaciers originating in the cirques on the side of the Dana plateau, as well as from the Gibbs Cañon glacier. The right lateral moraines in this instance are so great that they evidently deflected the glacier northward in the manner indicated by the present topography near the mouth of the cañon. As we progress it will be seen that the majority of the glaciers of the Mono basin during the later portions of their histories were deflected northward in a similar manner.

GIBBS CAÑON GLACIER.

The short cañon leading east from between Mt. Dana and Mt. Gibbs has been named Gibbs Cañon. This, like so many similar depressions in the High Sierra, was occupied by a glacier during the Quaternary, the form and extent of which are indicated by the present contour of the cañon in which it originated and by the piles of débris it left on melting. At the head of this cañon there is a deep cirque in which snowbanks frequently linger throughout the year. The ancient glacier which occupied it can scarcely be said to have had tributaries, yet it must have received considerable ice from the small cirques on the north side of Mt. Gibbs. One of these sheltered recesses still holds a small ice-body in which many of the characteristics of a true glacier may be distinguished.

There were two well marked stages in the history of the ancient Gibbs Cañon glacier. During the earlier portion of its existence it flowed out of the gorge and was deflected southward, so that the stream formed by its melting became tributary to the drainage of Bloody Cañon. In Pl. XXXIV the indefinite moraines deposited during this advance are shown to the left of the mouth of the gorge, as it appears in the illustration. It is only by careful attention in the field, however, that the ridges due to the deposition of ice-borne débris can be distinguished from ridges formed by erosion.

After the first advance, the glacier retreated at least as far as the mouth of the cañon; subsequently it advanced again with a greater volume than at first, and was deflected northward so as to deliver the stream formed by its melting into Leevining Creek. As previously mentioned while describing the ancient glacier of Leevining Creek, the glacier from Gibbs Cañon may have been a tributary to it during the height of the glacial epoch. The moraines formed

UPPER PORTION OF LEEVINING CAÑON.
From a photograph.

during the last advance of the Gibbs Cañon glacier are unmistakable, as may be seen on inspecting the illustration forming Pl. XXXIV. This view is from a photograph taken from the top of Williams Butte (see accompanying map, Pl. XVII). At the mouth of the cañon the ancient glacier was about three-fourths of a mile broad and had a depth of between five and six hundred feet.

The bed of the cañon is broadly U-shaped and is crossed by scarps and terraces in the manner common throughout the glaciated valleys of the Sierra. Far up, near the head of the gorge, there is a small rock-basin lake. Talus slopes of great size have accumulated at the base of the cliffs forming the cañon walls, since the ancient glacier melted away. These have grown by the constant addition of stones and rock masses detached from the cliffs, until at present they reach nearly across the ancient glacier bed.

BLOODY CAÑON GLACIER.

In the introduction some account was given of the appearance of Bloody Cañon as it exists to-day; in the present section it is our purpose to present a brief sketch of the glacier that occupied it in Quaternary times and imparted to it many of its most interesting features.

This cañon, unlike the gorges through which Leevining and Lundy Creeks flow, is not a low-grade, trench-like gorge leading into the heart of the mountains, but has a high grade all the way from the base to the summit of the range. The ascent in two miles is 2,100 feet. That it was formerly occupied by ice is abundantly proved by the contour of its bottom, its polished and striated rock surfaces, its lateral and terminal moraines, and the fine morainal embankments extending out into the valley from its mouth.

The Bloody Cañon glacier was one of the five ice-streams supplied by the Mt. Dana névé field. How far west of the present drainage of Bloody Creek it may have drawn its supply can not be determined with accuracy, but the former ice-divide was certainly some distance west of the present water-divide. It also received some increase from the southern side of Mt. Gibbs; but its principal lateral branches, as in the case of nearly all the ancient glaciers of the Mono basin, descended the southern wall of the gorge it occupied. Five and perhaps more secondary ice-streams originated in small, high-grade gorges on the south side of Bloody Cañon and contributed an abundance of angular débris to the right lateral moraine of the trunk glacier. The bed of the largest of these feeders is shown on the left in Pl. XXXV, and is seen also in the pictorial illustration presented on Pl. XXXVI.

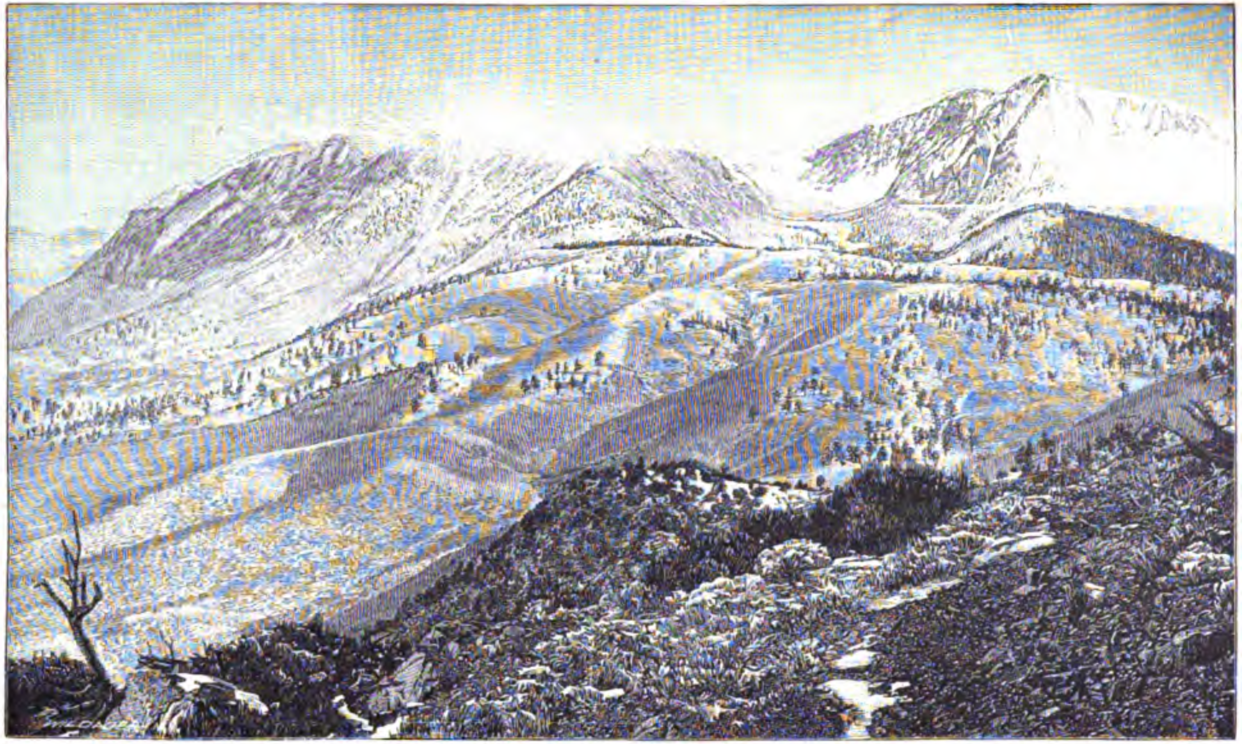
The length of the Bloody Cañon glacier, from the present divide on the crest of the mountains to the extremity of the morainal em-

bankments in Mono Valley, is about six miles. The distance from the divide to the base of the range at the point where the gorge passes from rock to alluvium, within the bed of the former glacier, is a trifle over two miles. The morainal embankments prolonged into Mono Valley as free walls of débris are four miles in length. The width of the ancient glacier near the mouth of the cañon was three-fourths of a mile and its depth at the same point 650 feet. The width of the bottom of the glacier at the site of the present lake was 2,300 feet, and its depth on the sides 550 feet. Proceeding down the gorge inclosed by the morainal embankments, which is literally the "form" left by the ancient ice-body, we find that it gradually contracted in width, at the same time decreasing in thickness, with remarkable uniformity, all the way to the extremity of the moraines it deposited. On Pl. XXXV, the contour lines are drawn with a vertical interval of 25 feet, which, together with the scale of the map, will enable the reader to make accurate measurements of such features of the ancient glacier as may be desired.

Each of the morainal embankments has a double and in places a triple crest. The outer crest is usually the highest and was formed previous to the smaller ones within. The latter were deposited when the glacier was somewhat contracted, and record successive stages in the retreat of the ice. On tracing the inner crests along the sides of the embankments it will be found that they decrease in height more rapidly than the crest of the main embankment in the direction in which the glacier flowed and finally join a terminal moraine which crosses the glacier bed, thus forming a long loop, the closed end being down stream. The crest line of each of these loops of débris records the outline of the surface of the glacier at a definite period in its retreat. If, after a loop has been made, a glacier retreats for a time and then pauses, and for a considerable period deposits débris along its sides and at its extremity, a second morainal loop will be formed within the first, its sides being lateral moraines and its end a crescent-shaped terminal. The double crests of the morainal embankments and the compound nature of these structures throughout thus become intelligible.

It will be remembered that the moraines of Lundy and Leevining Creeks are also compound. In the similar deposits about the mouths of Parker Creek and Rush Creek Cañons a repetition of this phenomenon may be observed, as will be described when these accumulations receive attention. The most typical examples of compound morainal embankments in the Mono basin, however, are furnished by the deposits we are now considering.

The minor characteristics of these moraines will be considered in the discussion of glacial phenomena which follows the present section. The main feature of interest which presents itself on studying them is the fact that they record at least two well marked periods



GIBBS CAÑON, FROM THE TOP OF WILLIAMS BUTTE.
From a photograph.

of advance in the glaciers which formed them and two periods of retreat, the last being prolonged to the present time.

During the first advance the glacier was deflected slightly southward on leaving the cañon, and built out parallel embankments for a distance of three miles and a half. The materials deposited during this advance are shown on the left of the main Bloody Cañon morainal embankments (Plate XXXV). They project from beneath the later formed moraines, and, as they appear at present, bear evidence of considerable modification by weathering, when compared with the fresher deposits which in part overlie them. Their crests are rounded, and the trough between them has been filled to a moderate extent by fine alluvium which has obscured the old stream channel that must have previously existed.

At the second advance of the ice it was probably thicker and its bed more elevated than during the first extension, and it crossed its first-formed embankment in the manner shown on the accompanying map (Pl. XXXV). The second prolongation of the glacier was somewhat greater than the first, and at its terminus it was deflected slightly southward, as in the previous instance. The limit of this advance is recorded by the small embankments shown at *a* (Plate XXXV). The evidence that the deposits at *a* are a pair of embankments, is less definite than that furnished by the deposits left by the first advance, and admits of another interpretation. They may be considered as right laterals, formed during separate advances. If this view is correct, then these deposits indicate two prolongations, with an interval of retreat. These fluctuations were minor features, however, in the history of the glacier. How far the ice foot retreated after the deposition of the accumulations at *a* is not recorded, but on increasing again it crossed the previously formed moraines, made another advance on the plain, and reached its maximum extent. For a third time the end of the glacier was deflected southward, so that the lower portions of the embankments formed during each advance are nearly parallel.

In the following diagrams two cross profiles of the moraines described above are presented, the positions of which are indicated on the accompanying map (Pl. XXXV.) The upper figure is a profile at the point where a lake is inclosed by the embankments. The lower one was taken near the lower end of the deposit and shows a profile of both the newer and the older moraines. In all cases it will be noticed that the right lateral embankment is much more massive than its companion. The figures on the diagrams show the elevation of various portions of the profiles above the highest water line of the lake which formerly flooded the basin. These profiles are also instructive as showing approximately the extent to which débris accumulated beneath the glacier.

In these embankments we have the record of two important advances, and the terminal moraines show that there were three considerable pauses during the last retreat of the ice. The terminals that may have been formed during the retreats that followed the first advance were obliterated during the final prolongation. It is

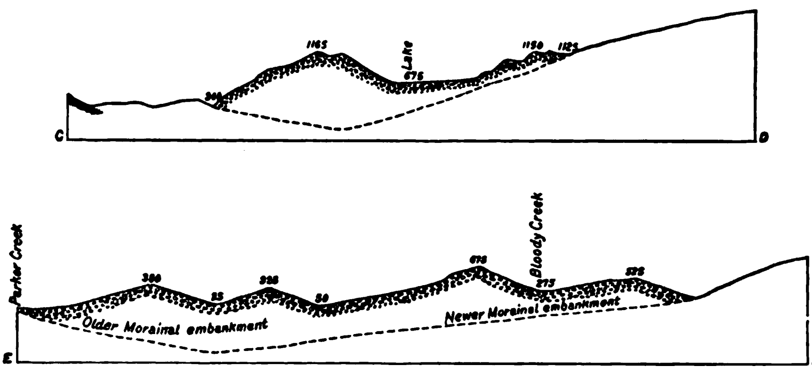


FIG. 4. Cross profiles of morainal embankments at the mouth of Bloody Cañon. Vertical and horizontal scale: 1 inch = 3,100 feet.

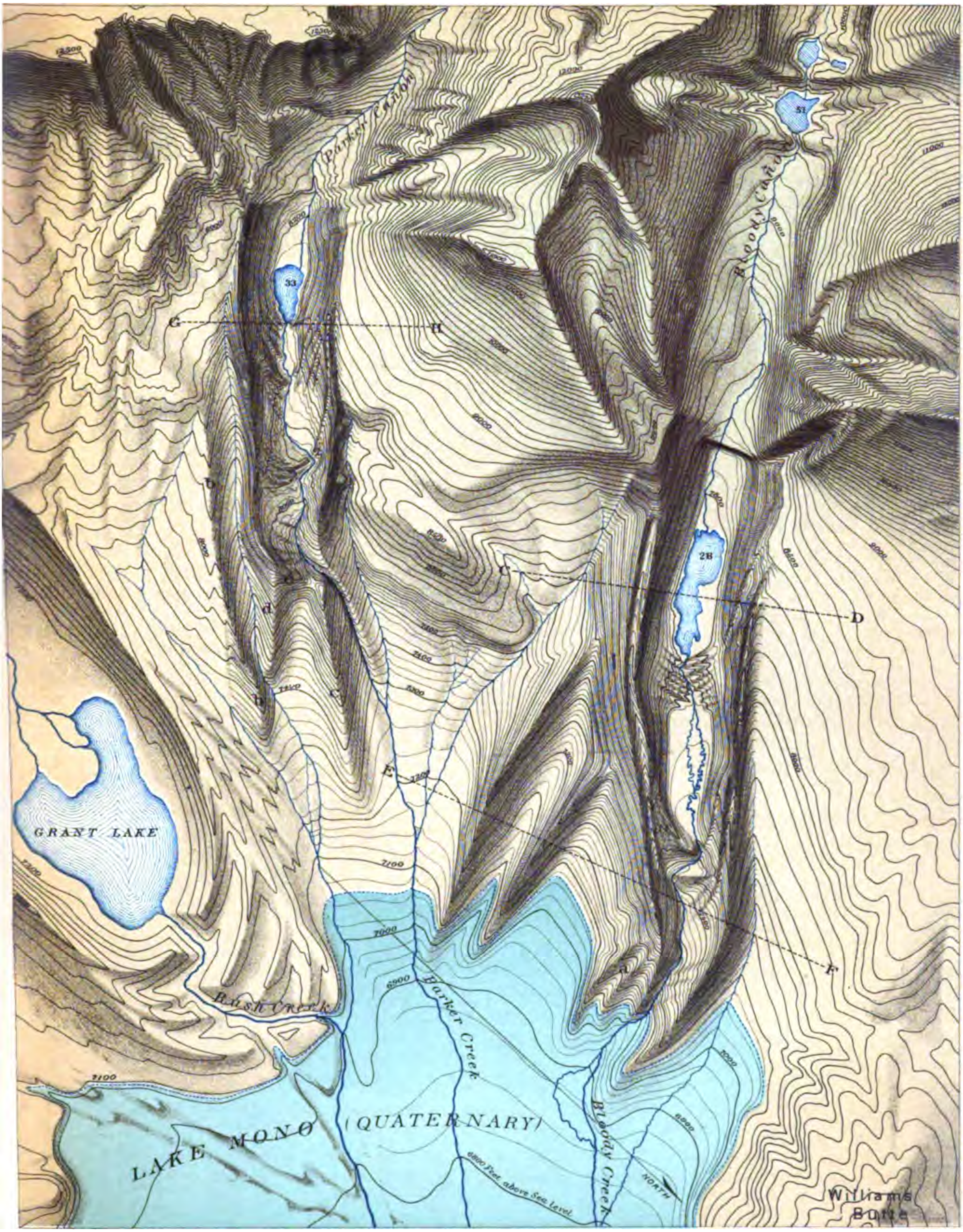
believed by the writer, as will be more fully explained on a subsequent page, that the deflection of the advancing glacier from its former bed during its second and probably during its third advance was caused by the obstruction presented by a previously formed terminal moraine.

The three advances and corresponding recessions of the Bloody Cañon glacier evidently indicate climatic oscillations of considerable duration. The advances were the result of an increase in the névés; in other words, they were periods of considerable length during which the annual snowfall on the mountains exceeded the quantity removed by melting and by evaporation. The retreats indicate with equal certainty that the reservoirs were becoming exhausted; or, in other words, the combined loss in the névé and in the glacier proper more than counterbalanced the supply.

PARKER CAÑON GLACIER.

In a previous essay already referred to, entitled, Existing Glaciers of the United States, the name Parker Creek glacier was given to a small ice-body still remaining in one of the cirques in the south wall of the cañon from which it derives its name. In the present paper we shall confine our attention to the history of the Quaternary glacier of Parker Cañon, which was in part derived from the same cirque.

The ancient Parker Cañon glacier was the most southerly of the ice-streams supplied by the Mt. Dana névé field. Like the glaciers



W. D. Johnson, Topographer. I. C. Russell, Geologist.

MORAINAL EMBANKMENTS OF PARKER AND BLOODY CAÑONS

Contour Interval over principal moraines 25 feet
" " elsewhere 100 "

Scale 1:50,000.

0 ¼ ½ ¾ 1 2 3 Miles.

previously described, it derived its largest lateral tribute from the southern wall of the cañon it occupied. Only a single tributary entered it from the north; this was comparatively small, and probably did not extend far enough to join the main stream, except during the height of the glacial epoch. The trunk glacier descended a high grade cañon, with many precipices and terraces, for a distance of about two miles. It then emerged from a magnificent gateway and advanced three miles and a half into Mono Valley. Like its companion in Bloody Cañon, it had at least three stages of advance, separated by periods of varying length, during which the ice retreated. At the first recession the end of the glacier was withdrawn at least to the gateway of the cañon, and how much farther is unrecorded. The second retreat is thought not to have been so great, but evidence on this point is extremely meager.

During the first advance of which we have any knowledge the right lateral embankment shown at *b*, on Pl. XXXV, was formed. This moraine is now much rounded, and bears evidence of having been exposed to atmospheric degradation for a longer time than the other similar deposits in the series, and is in this respect comparable with the oldest morainal embankments deposited by the Bloody Cañon glacier. A portion of the left lateral embankment, formed at the same time, is shown at *c* on the same plate. After the deposition of these moraines the glacier retreated and subsequently re-advanced about as far as at first, but with a somewhat diminished width, and deposited two embankments as in the first instance. The northern one coincides with the corresponding moraine formed during the first advance, but the one deposited on the southern border of the ice-stream is a free embankment within the older structure. The end of the right lateral embankment built during the second advance is shown at *d*, Pl. XXXV. Following this advance came a retreat, the extent of which can not be told.

The glacier subsequently advanced a third time and deposited the highest and best preserved moraines in the series. During this period of increase the ice followed its former bed until it reached three-fourths of its previous extent, was then deflected sharply to the left, and broke through the left lateral moraine formed during the second advance. The cause of this sudden deflection, if our interpretation of the phenomena be correct, was the presence of a terminal moraine, left by the glacier during its previous retreat, which formed a dam in the trough formerly occupied and caused the ice to flow across the lateral moraine. The channel thus opened is still occupied by Parker Creek and is a deep gorge in bowlders and morainal débris. When the course of the glacier was changed, the right lateral moraine continued to be deposited on the border of the ice and was prolonged so as to partially bury the terminal moraine that caused the deflection. The lateral moraine did not extend

completely across the old terminal one, however, but ended in a steep bluff, at the point marked *e* (Pl. XXXV). Although the glacier breached its left lateral moraine at the time it was deflected, it did not flow through the opening and deposit moraines beyond. At this critical point the advance of the glacier was checked and the final retreat began. The stream formed by the melting ice flowed through the breach made in the older lateral moraine and has held this course to the present day.

From the place where the last advance of the ice was checked, back to the gateway of the cañon, the morainal embankments are especially regular and well preserved, and are remarkable for the sharpness of their crests. A cross section at the site of the present lake is presented in the following figure:

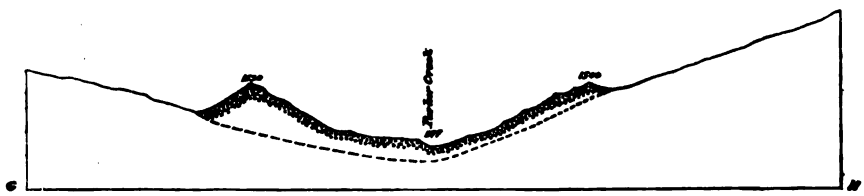


Fig. 5.—Cross profile of Parker Cañon morainal embankments. Vertical and horizontal scale: 1 inch = 1,871 feet.

During the final retreat of the ice there were three definite halts, recorded by three well defined terminal moraines which cross the glacial trough above the point where the last advance was checked. Each of these terminals has the form of an unsymmetric crescent, with the sharper portion of its curve on the north side of the trough. They are highest and broadest at their southern extremities, and the stream which drains the ancient glacier trough invariably crosses near their northern ends. All these features are a repetition of what has been observed in Bloody Cañon, and are of interest as illustrating the character of the terminal moraines which obstructed the advance of the ancient glaciers during their second and third periods of extension, causing them to abandon their former beds and to breach their left or northern morainal embankments.

All the features of the Parker Cañon moraines are so faithfully represented on Pl. XXXV that further description seems unnecessary. As may be determined from the map, the glacier, during its last advance, was half a mile broad and had a depth of 750 feet at the gateway of the cañon.

RUSH CREEK GLACIER.

The névé field formerly occupying the basin now drained by Rush and Silver Creeks was about twenty-four square miles in area, and supplied nearly all the ice that reached Mono Valley through the horseshoe-shaped cañon in which Silver, Gull, and June Lakes are

situated. This glacier was by far the largest within the hydrographic basin of Lake Mono. Before reaching the plain it was divided into two branches by a high rocky spur, which we name Division Butte. On the sides of this butte the débris carried on the surface of the glacier was stranded at the elevation of 1,600 feet above the cañon bottom on either hand. After passing the butte, the ice-stream formed two branches, which for convenience of description we name the east and west divisions.

The east division was much the larger and expanded somewhat on getting clear of the mountains; after flowing two miles and a half from the mouth of the cañon, it was again divided on coming in contact with a group of hills, on which bowlders were stranded in the same manner as on Division Butte. The west division also increased in breadth on leaving the cañon, but continued on as a single ice-stream and built up the magnificent morainal embankment now inclosing Grant Lake. Before passing Division Butte the Rush Creek glacier was about three miles broad; the distance between its moraines at their extreme limit is between five and six miles. The spreading of the ice in each division of the glacier, after leaving the cañon through which it descended, was greater than in any other of the Mono basin glaciers.

A peculiar change of drainage resulting from the action of this glacier is described below and will be best understood by reference to the accompanying map (Pl. XVII). One unfamiliar with the geology of the basin will be surprised to find that June Lake, which lies at the eastern end of the horseshoe-shape cañon we have described, and partially without the mountains, instead of discharging its drainage northward into Mono Valley, as would seem most natural, drains southward into the hills and is tributary to Rush Creek. The ancient drainage has been reversed by the deposition of morainal débris; we have therefore called the stream draining June and Gull Lakes, Reversed Creek. The drainage before the site of June Lake was occupied by a glacier must have been northward. At present the waters form cascades as they descend over the smoothly glaciated rocks and join Rush Creek just before it enters Silver Lake.

The main part of Rush Creek glacier, before passing Division Butte, had the form of a horseshoe; the deep trench that it left on melting still remains as indisputable evidence of its former magnitude. Between the branches of the horseshoe the ice was confluent up to the point where Division Butte interrupted the stream. The central portion of the glacier just before reaching the butte was never more than a few hundred feet thick. The main discharge was through the branches of the deep trench inclosing this central area.

The névé field of the Rush Creek glacier was far less simple than those of the glaciers previously described. It had many minor divisions which contributed secondary ice-streams to the main glacier.

The débris furnished by these various branches must have formed medial as well as lateral moraines on the surface of the compound glacier. Hence, terminal moraines were built when the foot of the glacier lingered at a definite point for a considerable time. The presence of well-marked terminal moraines is one of the features in which the records of this glacier differ from others in the same basin. The morainal embankments deposited by the glaciers previously described are open at their distal extremities; those formed by the Rush Creek glacier are connected by massive terminal moraines. The union of lateral and terminal moraines so as to form elongated loops is again seen here, and is typically illustrated about Grant Lake, as shown in the southeast portion of the map forming Pl. XXXV. The main walls of débris inclosing this lake are 1,000 feet high near the gateway of the gorge and have an inner slope of from twenty to twenty-five degrees. Within the main embankment there are interior lateral moraines forming terraces or free ridges which have a steeper grade when followed in the direction of drainage than the crests of the principal embankments. The interior laterals descend nearly to the bottom of the trough, and merge into crescent-shaped terminals forming loops which sharply define the former extent of the ice-stream that built them. Similar interior ridges may be seen on the inner slopes of the moraines deposited by the east division of this glacier, showing that it, too, has a complicated history. From the compound character of these moraines we learn that the parent glacier was subject to many fluctuations, some of which must have been caused by marked climatic changes. The left lateral embankment deposited by the west division is composed of not less than ten separate ridges, each of which records a marked change in the flow of the ice-stream that built them. The first formed loops were more widely spread than the subsequent ones, but were not so high. But the embankments are too complex to admit of the determination of a definite sequence of events. The glacier, during its various stages, occupied the same bed, so that unquestionable evidence of alternate advances and retreats, such as has been found in the case of the Gibbs, Bloody Cañon, and Parker Creek glaciers, is not apparent. The fact, however, that the morainal loops formed during the earlier portions of the glacier's history are much lower than those of later date seems to indicate that the first advance was followed by a retreat and a subsequent advance, during which the ice flood was higher than at the time of its first maximum.

The morainal embankments of the west division start from rocky spurs on each side of the cañon and extend out on the plain, as we have said, as free ridges, resembling railroad embankments, in each of which there are a number of crests. The proximal end of each embankment is more sharply defined than in most of the similar glacial deposits of the basin. On either side, however, at the imme-

diate mouth of the cañon, the embankments have been broken and portions of these crests carried away. The breach in the left embankment is evidently due to the action of streams which flowed down from the steep slope above; but the break in the right lateral must have been caused by the glacier itself. A satisfactory explanation of the manner in which the glacier removed a portion of its previously formed embankment is not apparent.

At the gateway of the cañon on the west side of Division Butte the rocks are conspicuously glaciated, but are so steep that but little débris remains upon them. Farther within the cañon nearly the entire bed of the ancient ice-stream is lined with débris, which forms a regular, even slope, except where broken by rocky spurs. Above the terrace formed by the upper limit of this sheet of morainal material the rocks have been carved into the forms characteristic of subaërial erosion. The contrast between the glaciated and the non-glaciated portions of the cañon is well marked throughout the horseshoe-shaped trench.

The east division of the Rush Creek glacier was much less simple than the one we have just described. The broad depression marking the former extent of this branch of the ice-stream is strewn with bowlders that seem to be without definite arrangement when observed near at hand. From the top of Division Butte, however, this débris is seen to form regularly curved lines, after the manner of terminal moraines. Well defined terminals of large size, like those inclosing Grant Lake, are wanting. The compound character of the lateral embankments may here be distinguished, but the extremities of most of the ridges are poorly defined. A stream channel in the depression formed by each of the branches of this division indicates the amount of excavation accomplished by the water derived from the melting ice. At the end of the eastern branch, a coulée of glassy rhyolite has flowed from a vent among the Mono Craters into the bed of the glacier since the ice was melted and has covered a portion of the ancient trench. Within the bed of this branch rise several crags of basalt, fresh and ragged in appearance, unmarked by glacial erosion, and not covered with glacial deposits. They are evidently more recent than the morainal débris through which they rise, and hence are of post-glacial date.

Less than half a mile north of June Lake there is another place where the glacial and volcanic records of the basin overlap. At this locality a small basaltic crater has been overrun and much eroded by the ice of the east division of the Rush Creek glacier. When the glacier melted, granitic bowlders were stranded on both the inner and outer slopes of its rim. The course of the ice being from south to north, the northern wall of the crater was carried away and its bottom is now an extension of the plain surrounding

the crater to the northward. From each end of the fragment of crater remaining there is a trail of morainal débris stretching northward and finally merging with the plain. The level tract skirting the crater on the north and west is of fine material, without bowlders, and is surrounded on the north by an inclosing wall of morainal material, on the slope of which are faint beach lines. A notch in this terminal moraine shows that the lakelet which once filled the little basin it partially incloses overflowed northward. The southern wall of this lakelet must have been formed by ice which filled the cañon where June Lake is now situated. During the maximum extension of the Rush Creek glacier the crater mentioned above was buried by more than a thousand feet of ice, which ground down its summit and probably carried away its northern wall. After the ice melted its site was occupied by the waters of a glacial lake. The crater stood directly in the path of the great ice-stream, and one would think that it must have been removed almost completely had it been subjected to ice erosion throughout the glacial epoch. As its shape is still distinct, the suggestion that it may have been formed during an interglacial period seems pertinent. Farther reference to the connection of glacial records with volcanic phenomena will be made in the division of this paper devoted to the volcanic history of the basin.

I have suggested that, because the main ridges of the embankments formed by the Rush Creek glacier are so much higher than those first deposited, it is possible they may indicate an independent advance of the ice. Better evidence, however, that there were two well-marked periods in the history of this glacier, as in the case of neighboring ice-streams, is furnished by buried moraines to be seen at a considerable distance below the well defined embankments extending below Grant Lake. These deposits are covered with lacustral sediment, so that their presence is made manifest only by huge, half-buried bowlders which occur half a mile or more below the end of the more recently formed moraines. These buried deposits probably agree in date with the first-formed embankment of the Bloody Cañon and Parker Cañon glaciers.

It might be suggested that the bowlders to which we have called attention were iceberg drift and indicate that the Rush Creek glacier during its earlier history entered the Quaternary lake and formed icebergs on which bowlders were floated, but their distribution does not support this hypothesis. They are not widely scattered, but are limited to a district just in front of the fully visible moraines.

The features which the Rush Creek moraines have in common with other glacial deposits of the basin, as, for example, perched blocks, lake basins, sheathing of débris in the cañon, etc., will receive attention in the following section.

GLACIAL PHENOMENA.

GLACIATED CAÑONS.

It is well known that valleys once occupied by glaciers have a different form from those shaped by stream erosion simply. The former are usually U-shaped in cross profile, while the latter are V-shaped. This distinction holds good in the Sierra Nevada, and is well illustrated by the cañons of the Mono basin, the majority of which are typical examples of glaciated gorges. Some of these are so broadly U-shaped that their bottoms appear nearly flat. In some instances this feature is due to the deposition of débris, but in others the true rock bottom forms a plain, sloping with a gentle grade in the direction of drainage. In cross-section the cañons of this character still retain the characteristic form, but the bottom of the profile is a nearly horizontal line. This is illustrated especially by the gorge of the Tuolumne River, the bottom of which is a plain half a mile broad, with rock in situ all the way across.

The glaciated cañons of the Mono basin may be divided, in reference to grade, into two classes, viz, low-grade and high-grade gorges. There are two, Lundy and Leevining, that are typical examples of low-grade gorges. These extend far back into the mountains with moderate grades and are terminated at last by precipitous cliffs. At the head of Leevining Cañon, especially, the character of the cliff that crosses the head of the gorge like a huge wall is well displayed. Lake Cañon is also an example of a low-grade gorge which extends deep into the mountains and terminates abruptly. With these may also be placed the horseshoe-shaped trough through which Reversed Creek and a portion of Rush Creek flow. The deep, low-grade valleys now occupied by the Merced, San Joaquin, and Tuolumne Rivers are also typical examples of this variety of glaciated cañons.

The high-grade gorges are illustrated by Gibbs, Bloody, and Parker Cañons. These are short, without important branches, and lead directly from the base to the crest of the mountain range.

The two classes of gorges designated above have well marked characteristics, and are of service in describing the sculpturing of the Sierra Nevada, but are perhaps not otherwise important as taxonomic features. The difference between low and high-grade cañons is caused principally by the influence of preglacial topography on the flow of ice-streams. The low-grade are mostly ancient stream channels that were deeply eroded before being modified by ice action; the latter must also have been channels of drainage previous to the glacial epoch, but owing to the fact that their drainage areas are small they were not extensively eroded since the mountains had their present form. The névé fields drained by the smaller channels were of limited extent, and the resultant glaciers were usually simple.

Another peculiarity of the low-grade gorges of the Mono basin

is that they head back of the general trend of the mountain crest and derive a large part of their drainage from the opposite slope. This feature is illustrated by Lundy and Leevining Cañons. Mt. Warren, one of the finest mountain masses on the western border of the Mono basin, discharges all its drainage into Lake Mono; Mt. Conness, situated still farther from the eastern mountain face, delivers all the drainage from its northern slope into the same reservoir. These features in the drainage of the Mono basin are analogous to the stream channels of the Wasatch Mountains, which rise to the eastward of the main peaks of the range, but discharge their waters into Great Salt Lake. Before the origin of the drainage channels of either the Sierra Nevada or the Wasatch can be explained, however, it seems evident that we must know more than we do at present of the drainage of the Great Basin region previous to the initiation of its present topography.

SCARPS AND TERRACES.

A characteristic feature of the glacial cañons of the High Sierra, and one that has been observed in other regions, is that they do not have a continuous grade, but are crossed by an alternating series of scarps and terraces, the former being frequently two or three hundred feet high and the latter several hundred feet broad. The bottoms of the cañons are in fact Cyclopean stairways, rude and irregular, it is true, leading to the higher portions of the mountains. These features are most pronounced in the upper portions of the cañons and may be seen at many localities throughout the High Sierra. Many of the terraces hold rock-basin lakes or swampy meadows, while the scarps are mostly bare rock surfaces on which the inscriptions of the ancient glaciers can be read with unusual distinctness. Some of the characteristics of these scarps and terraces have already been noticed in the introductory chapter, where the general appearance of Bloody Cañon was described. The cliffs terminating some of the low-grade gorges, as the Doré Cliffs at the head of Lundy Cañon, for example, belong to the same group of phenomena.

It might be supposed that these scarps and terraces were produced by changes in the texture and hardness of the rocks in which the cañons were excavated; and another hypothesis, proposed by E. Reyer, is that they are caused by post-glacial faulting;[1] but the writer's observations failed to sustain these hypotheses. Apparently the steps in glaciated cañons are allied to glacial cirques, and the consideration of their origin will therefore be deferred for the present.

[1] Zwei Profile durch die Sierra Nevada, Neues Jahrbuch, IV Beilage-Band, 1886, p. 303.

MEASURE OF GLACIAL EROSION IN CAÑONS.

The present relief of the High Sierra has resulted from the erosive action of both water and ice upon an upheaved mountain mass. The elevation of the range is due to upheaval, but all the topographic features, on which the variety and grandeur of the scenery of the region depend, are the result of degradation. The topographic forms produced by the action of water and the modifications due to glacial ice are so individual in their characteristics that the geologist is nearly always able to distinguish them at a glance.

To one familiar with the scenery of the High Sierra it is apparent that nearly all the main features in the relief of the mountains have resulted from the action of running water. This conclusion is so self-evident and has been recognized by so many observers that we need not delay to present the evidence on which it rests. All the deeper cañons and gorges are the work of streams, but their contours have been altered by the action of ice. The old stream-channels afforded avenues of escape for the snow of the High Sierra when a decrease in temperature changed the drainage from a liquid to a solid form.

This is manifest to every one who has examined the profound valleys descending from Mt. Lyell, but is shown still more plainly in the cañons of the Mono basin.

Lundy Cañon, for example, is a low-grade trench about seven miles long, the average width of which in its lower portion, where it is partially filled with débris, is one-third of a mile at the bottom, and about a mile from top to top of the cliffs inclosing it. Its average depth is between two and three thousand feet. This gives five cubic miles as an approximate estimate of the amount of rock that has been removed in order to form the gorge, without reckoning its lateral branches. Near the mouth of the cañon there are lateral moraines, together with some accumulations of morainal material in the bottom of the gorge, and at its extremity there are morainal embankments; these contain all the coarser débris removed from the gorge through the agency of ice. Much of the finer material resulting from glacial action was deposited in the lake and formed a delta between the extremities of the morainal embankments. With the exception of the very fine silt carried to distant parts of the lake, we are able to make an approximate estimate of the amount of material removed from the cañon by ice. If we assume that half of the fine material was deposited in the delta, we find that about one-fiftieth of a cubic mile represents the volume of glacial débris about the mouth of the gorge. Even if this estimate is quadrupled it fails to account for the formation of the cañon through the agency of ice.

The great discrepancy between the quantity of glacial material deposited at the mouth of Lundy Cañon and the magnitude of the excavation from which it was derived may be seen at a glance on in-

specting the accompanying map (Pl. XVII). This same discrepancy is also noticeable in the sketch forming Pl. XXXI, which represents the moraines at the mouth of the cañon as seen from Black Point. If all the material in the moraines and delta were replaced within the cañon from which it was derived, the present aspect of the gorge would scarcely be altered. This conclusion is rendered still more forcible when it is remembered that the ancient glacier of Lundy Cañon derived a very large portion of its débris from Lake Cañon and from the northern slope of Mt. Conness.

In the case cited above, the conclusion that the effect of ice erosion was small in comparison with the entire amount of work performed in excavating the cañon seems well founded, but yet requires qualification. We have no measure of the quantity of very fine silt removed from the gorge by glacial streams and deposited in remote parts of Mono Valley. It is therefore impossible to make a definite quantitative determination of the amount of erosion due to ice. Other observers, it is true, might give a much higher estimate for the amount of fine material deposited in distant parts of the lake, and conclude that profound glaciation had occurred.

Evidence indicating the slight effect of ice erosion in comparison with the total amount of excavation necessary to produce the cañons of the Mono basin might be found by comparing the size of the moraines and deltas at the mouth of Leevining Creek, with the amount of erosion performed in order to produce the gorge through which it flows. In this instance, also, it is impossible to obtain a measure of the fine material removed, hence any quantitative measure of the amount of work done by the former glaciers must be uncertain.

All the valleys examined by the writer on the western slope of the High Sierra have a history similar to that of the cañons of the Mono basin and add strength to the conclusion that the main glaciers of the region during Quaternary times followed previously formed stream-channels which were modified and enlarged by their action.

It is the opinion of the writer that the excavation of many of the valleys of the Sierra Nevada began long previous to the Quaternary, and are in fact relics of a drainage system which antedates the existence of the Sierra as a prominent mountain range.

Those who seek to account for the formation of the Yosemite and other similar valleys on the western slope of the Sierra by glacial erosion should be required to point out the moraines deposited by the ice-streams that are supposed to have done the work. The glaciers of this region were so recent that all the coarser débris resulting from their action yet remains in the position in which it was left when the ice melted. If the magnificent valleys referred to are the result of glacial erosion, it is evident that moraines of great magnitude should be found about their lower extremities. Observation has shown that

débris piles of the magnitude and character required by this hypothesis are notably absent.

It is perhaps not digressing too far to state that the writer, while visiting the Yosemite, could not avoid adopting a hypothesis advanced some years since by J. D. Whitney, to the effect that the main characteristics of the valley are due to dislocation; or in other words, that the orographic block beneath the valley has subsided. No facts were observed, however, conflicting with the conclusion of Clarence King that the valley was occupied at least in part by glacial ice. The majestic domes of the Yosemite region have not been rounded by glacial action as some writers have supposed, but have been produced by the weathering of granite, in which a concentric structure on a grand scale was produced when the rocks were in a plastic condition.

HIGH LATERAL CAÑONS.

In a number of instances in the Mono basin the low-grade glaciated cañons receive branching cañons at a considerable elevation above their bottoms, the branches also having a low grade. This is illustrated where Lake Cañon opens into Lundy Cañon. Each of these gorges has an approximately horizontal bottom near the place of union, but the former is a thousand feet higher than the latter. The stream flowing through Lake Cañon descends precipitously over a rocky face in order to join Lundy Creek. The bottom of the higher cañon is about on a level with the main lateral moraine in the lower cañon. The same series of phenomena is repeated where Silver Creek descends over a rocky face to join Rush Creek; and, again, at the point where Rush Creek leaves its elevated drainage basin and forms a beautiful cascade on entering the horseshoe-shaped cañon in which Silver Lake is situated. At these localities, also, the bottoms of the lateral cañons where they join the main gorge are approximately on a level with the lateral moraine deposited by the trunk glacier.

It might be assumed that the main cañons had been excavated by glacial action more deeply than the lateral branches, owing to the greater eroding power of the glaciers which occupied them. This is a simple and natural explanation of the conditions observed, and if we admit the great amount of erosion usually assumed for ancient glaciers, it must be accepted as an adequate cause for the great strength of the main channels of ice discharge. To the writer, as previously stated, it appears that the main work of sculpturing in the Sierra Nevada and the production of the variety of scenery for which those mountains are remarkable, is to be attributed to water erosion, while only minor features, such as the rounding and broadening of the bottom contours of the valleys, the smoothing of the higher mountain slopes, the polishing and striation of rock surfaces, etc., are to be referred to glacial action. With this conclusion in

mind, the great inequality in the depth of the main glacial troughs and of their lateral branches is too great a work to be ascribed to the erosive power of ice.

GLACIAL CIRQUES.

One of the most striking features in the sculpturing of the High Sierra is furnished by the grand amphitheaters or cirques occurring about the more elevated peaks and crests. These are deep semicircular excavations, bounded on all sides, except that through which the drainage escapes, by bold cliffs or by perpendicular walls from a few hundred to more than a thousand feet in height. The bottoms of these excavations are often depressed below that portion of the rim through which the drainage escapes, and form rock basins; at other times the basins are partially inclosed by débris, and in some instances they have well-formed terminal moraines across their outlets. In these hollows there are transparent lakes of azure blue, which reflect the grandeur of the sheltering walls with wonderful distinctness from their unruffled surfaces. A horizontal cross-section of a cirque is semicircular or horseshoe-shaped, and in certain portions of the range these are so numerous that they give a scalloped contour to the faces of the cliffs. The interiors of some of the amphitheaters are terraced in the same manner as are the bottoms of the cañons leading from them—a feature which has been observed in the cirques of the Rocky Mountains as well. Nearly all the various branches of the ancient glaciers of the High Sierra headed in deep recesses of the character above described. In places, the cirques occur on either side of a fragment of table land, and have been eroded back until only a knife-edge of rock, so narrow and broken that the boldest mountain climber would hesitate to traverse it, is all that divides one profound depression from another. Examples of this nature are common about Mts. Lyell and Ritter and find a number of typical illustrations in the cliffs of the Kuna and Koip crests. At the head of Rush Creek are a number of separate cirques, each holding a gem-like lakelet, in which the various branches of the stream draining the basin have their source. Silver Creek heads in a magnificent amphitheater formed by the union of several cirques, which during the height of the glacial epoch was completely filled with névé. On the south side of Kuna and Koip Peaks are two vast amphitheaters, which rank among the finest in the Mono region. The positions of others may be distinguished on the accompanying contour map (Pl. XVII), but no topographic delineation or word description can convey the impressive grandeur of some of these vast, shrine-line recesses that have been sculptured during the lapse of centuries from the rugged cliffs of the High Sierra.

In general the cirques open northward, but many exceptions to this rule can be found, especially about the head waters of Rush and Silver Creeks.

It is in the cirques about the higher peaks that living glaciers are still found, and those not harboring perennial ice are deeply filled with snow during a large portion of the year. The slow melting of the snow and ice in these reservoirs feeds the rills which join one with another to form the creeks flowing into Lake Mono. The balance between the climatic conditions favorable to the existence of glaciers and those which insure their disappearance is here nicely adjusted, and should the equilibrium shift to the side of greater congelation, these ancient cirques would be the first points to exhibit the changed condition. They were the fountains which gave birth to the ancient glaciers, and were also the last strongholds to be abandoned when the reign of ice approached an end.

Such amphitheaters are known in all mountain regions where glaciers have existed. It has been the good fortune of the writer to examine them on some of the higher peaks of Colorado and New Mexico, about the crests of the Wasatch and East Humboldt Mountains, as well as in Switzerland and New Zealand. Their origin is somewhat problematic and has occasioned much discussion, as is well known to all who have followed the growth of glacial literature.

In an article on the formation of cirques, by T. G. Bonney,[1] an attempt was made to prove that these peculiar features of mountain sculpture are the result of stream erosion, and owe few if any of their characteristics to ice action.

The studies of B. Gastaldi[2] on the effects of glacial erosion in Alpine valleys led him to reject Bonney's hypothesis and to conclude that they are a result of ice erosion.

The most extended as well as the most instructive essay concerning their formation that has come under the writer's notice is from the pen of Amund Helland, entitled On the ice fjords of North Greenland, and on the formation of fjords, lakes, and cirques in Norway and Greenland.[3] In this essay a clear and concise description of the cirques of Norway, Switzerland, and other regions is given, together with a brief summary of the various hypotheses that have been advanced in explanation of their origin. Strong evidence is also presented to show that they are a result of glacial action. In Helland's essay are included the views of Lorange, of the Norwegian Royal Engineers, who arrived at the conclusion that they are formed principally by the effects of great changes of temperature in the vicinity of glaciers. We quote Lorange's observations and conclusions as stated by Helland:

Under the glaciers in cirques, where a space intervened between the bed of the cirque and the ice, he saw a great many stones, some of which, sticking fast in the glacier, were quite lifted up from the bed of the cirque, while others were touching

[1] Quart. Jour. Geol. Soc., London, vol. 28, 1872, pp. 312–324.
[2] Ibid., vol. 29, 1873, pp. 396–401.
[3] Ibid., vol. 33, 1877, pp. 142–176.

or resting on it; he thinks it probable that, as the temperature around the glacier constantly varies about the freezing point, the incessant freezing and thawing of the water in the cracks in the rock may split it, and the glacier may do the work of transportation for the fragments thus broken loose. On examining the interior of an empty cirque we observe that a bursting, not a scooping out, of the rocks has taken place. . . . There is some difference between the exposed surface of the mountains and that beneath the glacier; for on the latter water at zero Centigrade is constantly dropping down, easily frozen by every draft of cold air under the glacier, and the glacier itself is always present to remove the blocks.

The writings of Penck, Löwl, and other European geologists might be cited here, but it is not my intention to review the entire literature of the subject.

Sufficient observations have been recorded to show not only that cirques are of nearly world-wide distribution, but that they are confined to glaciated regions, and are not found in mountains where undiputed records of glacial action are absent. This in itself is good evidence that they have resulted from glacial erosion. The same conclusion is indicated by the fact that as a rule they open northward; that is, they occupy positions where glaciers first appear when a lowering of temperature renders their existence possible, and where they linger longest when the climate ameliorates. It thus seems unnecessary to discuss in the present paper the various hypotheses which refer their origin to water erosion, crater elevation, etc.

The descriptions presented in the essays we have cited, together with the observations of the writer, show that the cirques of the High Sierra are typical of their class, and present all the features to be seen in other similar regions. It is thus rendered evident that if we can arrive at an acceptable explanation of their origin, it should explain the like phenomena in other regions as well. The writer has no mature theory to offer, but hopes to contribute something toward the desired end.

It is usually difficult to draw a definite line between a glacial cirque and the cañon leading from it. One is a continuation of the other. It is evident, also, that the walls inclosing a cirque have many features in common with the scarps so frequent in glaciated cañons. When the cirques themselves are terraced this analogy is rendered still more complete. The writer's studies in the High Sierra and elsewhere have led to the conclusion that such scarps and cirques result mainly but not wholly from glacial action. The initiation of the process, at least in the High Sierra, as in the case of many glacial cañons, must have been by subaerial erosion.

Lorange's observations show that when a névé fills a cirque it is capable of removing blocks of rock from the inclosing walls. The fact that these walls are rough and angular, instead of smoothly polished, is proof that there is but little abrasion during the settling and consolidation of the névé in the amphitheaters in which it accumulates. At the bottom of the depressions, however, the conditions are different. Intense glaciation there takes place, as is

attested by the rounded and striated surfaces, and by the occurrence of rock basins. The ice filling a cirque impinges with great weight upon its bottom and in its motion outward tends to deepen the excavation. At the same time the blocks loosened from the walls of the cirque are carried away by the outward flow of the ice. There are thus at least two processes which unite in enlarging and deepening these peculiar features of glaciated mountain tops.

When a glacier leaves a cirque and flows down a cañon the grade of which is uneven, the erosion of the ice-stream will also be uneven. The reason is that the ice in descending a steep slope exerts its greatest force at the base of the incline in the same manner as in the excavation of cirques. The tendency of a moving ice-stream in descending a steep slope is to increase the inequalities of its bed; this tendency, it seems probable, will lead to the formation of both scarps and cirques when the drainage of a high-grade valley is changed from a liquid to a solid form. To illustrate: The grade of mountain streams increases towards their sources, and when their gorges become occupied by ice the irregularities of their channels—caused principally by the meandering of streams, thus leaving projecting bosses on either side—may cause ice-cascades in the glaciers. An ice-cascade exerts the greatest erosive power at the base of the scarp which it descends, thus augmenting the inequality. At the same time the cañon is broadened and the minor features resulting from stream erosion are erased. The steeper the grade the more pronounced would be the action of the ice in remodeling and strengthening the major inequalities of its bed. The resulting scarps and terraces should therefore be most numerous and best defined near the heads of the channels in which they occur.

The formation of rock basins beneath glaciers belongs, apparently, to the same method of erosion that produces scarps and terraces. It will be remembered in connection with this subject that rock basins in high-grade cañons usually occur at the foot of steep slopes, and that many cirques contain basins of this character.[1] The alternation of soft and hard rocks may assist the development of these features, but in general their origin is independent of rock structure, and must seemingly be ascribed as stated above, to the unequal erosive power of glaciers in descending a cañon having an irregular grade.

GLACIAL EROSION AND DEPOSITION.

In the flow of streams the processes of erosion and deposition are carried on at the same time in different portions of their channels and in the same portions at different times. The result is the forma-

[1] It is not probable, however, that this is the only manner in which rock basins have been formed. The halting of a low-grade glacier at a given point for a considerable time might cause a depression to be eroded where sudden changes of grade did not occur.

tion of channels which are sometimes produced by erosion simply, but more frequently by combined erosion and deposition. Many analogies have been pointed out between the flow of streams and the flow of glaciers, and the study of the glaciers of the High Sierra leads us to conclude that channels formed or greatly modified by glacial action, like those produced by streams, are frequently due to the combined effects of erosion and deposition. In glaciated cañons it is common to find that the ridges have been ground down and partially removed, while the depressions have been filled with débris. As soon, however, as the bed of an ice-river has acquired the broadly U-shaped cross-section characteristic of glaciated cañons, both erosion and deposition are reduced to a minimum. When the cross-section of a cañon does not have a form which presents a close approximation to the typical U shape either deposition or excavation will be accelerated.

The power of glaciers to erode in certain portions of their courses and deposit in other portions has been observed by many geologists, and may be recognized not only in Alpine glaciers, but also in the records left by the continental glaciers which once existed in northwestern Europe and northeastern America.[1]

That it is the form and grade of a cañon principally, and not the nature of the material in which it is formed, which determines whether erosion shall take place or not, is shown by the manner in which the glaciers of the High Sierra at times eroded their beds and at times deposited material in order to form the trenches now remaining. Some of these cañons are lined with an inner sheathing of débris up to the height of the surface of the ancient ice-streams. This is noticeable in the Tuolumne Cañon and in all the gorges of the Mono basin, particularly near their mouths. The deposition of a general sheathing of débris within the trough occupied by a glacier takes place principally when the grade is low. Only very slight deposits of this nature are found in high-grade cañons. It follows from this that ice-streams, like rivers, erode most rapidly when their grade is high; when the slope of their channels becomes small, deposition frequently takes place.

Although the deposition of débris between a glacier and the walls of its cañon occurs when the grade is low, the lack of inclination may not be the predominating cause in promoting deposition. In the lower portions of glaciers, where their volume is diminished by melting, they often shrink away from the inclosing walls, leaving an open gap for the reception of débris. Such an occurrence may be observed at the present time in several of the glaciers of Swit-

[1] An extended summary of the views and observations of geologists both in this country and in Europe, with reference to this subject, has been published by W. M. Davis in a paper entitled Glacial Erosion. Proc. Boston Soc. Nat. Hist., vol. 22, 1882–'83, pp. 19–58.

zerland. In instances of this nature a sheathing of débris might be accumulated on the sides of a cañon while it was still occupied by a glacier, without special reference to the grade of the valley. These conditions are most frequently found in glaciers that are retreating.

That a glacier may flow through a cañon without excavating its bottom and sides is proved by the fact that the glaciers of Bloody and Parker Cañons at the time of their second advance re-occupied troughs between morainal embankments which had been abandoned by the ice at the time of the first retreat. These embankments, as already described, are free walls of unconsolidated débris. Had the form of the troughs not been in harmony with the flow of the ice during its second advance, excavation must have ensued. In illustration of this we see how completely the ancient talus-slopes have been removed from the cañons throughout the region under discussion. Again, in the case of the moraines of Bloody and Parker Cañons, as soon as the ice reached a portion of the trough that was deformed by the presence of a terminal moraine, the power of the advancing ice-stream to remove its inclosing walls of débris was at once asserted. The glacier in each case broke through its left lateral embankment and built a new trough with the earth, stones, and bowlders carried on its borders. During the second advance of the Bloody Cañon glacier the surface of the ice was between four hundred and five hundred feet higher than the previously formed embankments, and yet was strictly confined within the old trough for fully a mile and a half before being deflected.

The form of the bed which a glacier builds for itself when not confined by walls of rock illustrates the character of the trough that presents the least resistance to the advance of an ice-body of given dimensions. Apparently it is harmony or want of harmony between the form of a cañon and the bottom contour of a glacier, which determines whether erosion and deposition shall take place or not. That is, valleys seldom have the form characteristic of glaciated cañons, but are modified by erosion and deposition until their shape approaches that of a typical glacial trough. After this adjustment has been made there is comparatively little change of form produced by the flow of ice through them, so long as the grade of the channel is low; in high-grade gorges erosion must still continue.

In some instances in the Mono basin it seems as though the erosion of the ice in the bottom of a cañon had been less than the subaërial erosion above the glaciated surface, but this is not a safe inference, as the contour of the sides of a valley beneath glacial moraines can not be determined; besides, what atmospheric erosion has occurred since the glaciers melted has tended to remove material from the slopes above the moraines and add it to the glacial deposits at a lower level. A cañon of this character, after being exposed for a long time to atmospheric agencies might have a different slope

above and below the upper limit of the lateral moraine, which would be the only indication remaining to show that it had formerly been in part occupied by ice.

MORAINES.

Dirt and stones falling on the margins of a living glacier and borne along by it are called lateral moraines. When two glaciers unite and flow on side by side as a single compound stream, the left lateral moraine of one unites with the right lateral moraine of its companion to form a medial moraine along the central portion of the united stream. A trunk glacier, compounded of many branches, has many medial moraines, and, as it flows on to a point below the snow line and is melted, the material on its surface is deposited about its terminus and forms a ridge which is usually convex down stream. At both ends this terminal moraine unites with the lateral deposits accumulated along the margins of the glacier, thus forming an elongated loop. Glaciers with numerous branches usually have large accumulations of débris on their surfaces, and are capable of forming terminals of great size, providing the foot of the glacier remain stationary for a considerable period. Simple glaciers without tributaries are comparatively free from débris excepting on their immediate borders; in such a case the laterals far exceed the terminals in magnitude and may not be united at their lower extremities. Débris also accumulates beneath glaciers, as already stated while speaking of glacial deposition, and forms what are termed "ground moraines," as is well illustrated in the lower portions of all glaciated gorges of Mono Valley.

In glaciated cañons from which the ice has disappeared, one almost always finds accumulations of débris, arranged in lateral and terminal moraines in such a well-defined manner as to assure the most skeptical that ancient glaciers obeyed the same laws and produced the same general results as do living ice-streams.

Terminal moraines.—The majority of the ancient glaciers of the Mono Basin were short, simple ice-streams, without important branches; hence their terminal moraines are small.

A common feature in all the terminal moraines, excepting those deposited by the Rush Creek glacier, is the fact that they are not regularly crescent-shaped, but extend farthest down stream on the right hand or southern side of the troughs in which they occur and are much higher, broader, and in every way more massive at their southern than at their northern ends. It will be remembered that all the glaciers of the basin, excepting that of the Rush Creek Cañon, flowed eastward. In Leevining Cañon the inequality of some of the terminals is less definite than in other instances, indicating that the small medial moraines of the glacier were more evenly distributed on the surface of the glacier which formed them.

MORAINAL EMBANKMENTS AT THE MOUTH OF BLOODY CAÑON, FROM THE TOP OF WILLIAMS BUTTE.
From a photograph.

Lateral moraines.—The surface of a glacier is usually somewhat convex in cross-section, and the débris accumulated along its borders commonly rests against the ice and forms steep slopes on the sides. When the ice melts, this material is left as a ridge of greater or less magnitude, with its greater slope on the side formerly supported by ice. This is illustrated in the following diagram which we copy from W. S. Green's account of the glaciers[1] of New Zealand.

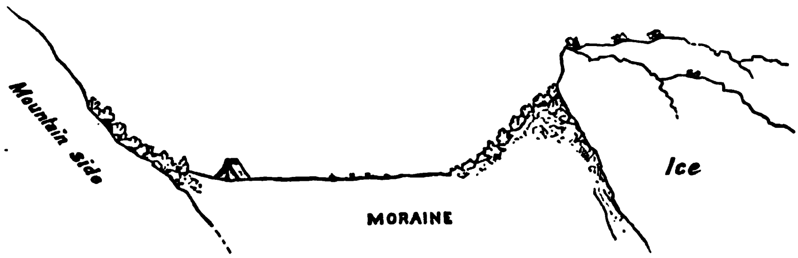


FIG. 5. Profile of lateral moraine, Ball Glacier, New Zealand.

Should the surface of a glacier be lowered it is evident that a second ridge of débris might be formed on the inner side of the older deposit, in the manner indicated below.

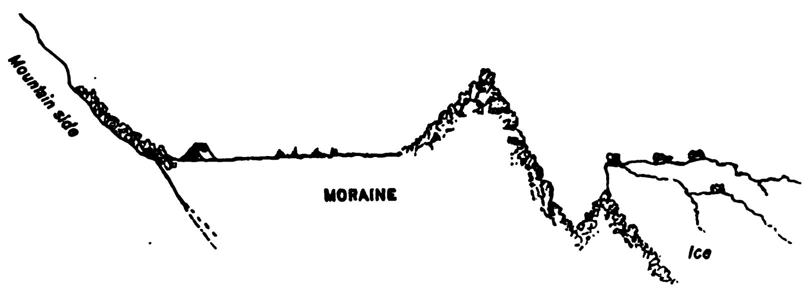


FIG. 6. Diagram illustrating the formation of compound lateral moraines.

Lateral moraines of this nature follow the borders of the ice-stream and have the same grade when followed along the sides of a cañon as the surface of the parent glacier. On the disappearance of the ice these long, level-topped ridges are left on the sides of the valley through which it flowed like the sticks and timbers stranded on the banks of a river at high water.

In the glaciated cañons of the Mono basin lateral moraines of this character are a conspicuous feature. They usually present the appearance of ridges or terraces on the sides of gorges, and in cross-section have profiles like that shown below. As the surface of the glacier which formed the higher deposits was lowered, other ridges of a similar character were accumulated within. Lateral moraines in many instances define the upper edge of a sheathing of débris lining

[1] The High Alps of New Zealand, p. 200. London, 1883.

In all the morainal embankments of Mono Valley, excepting those formed by the Rush Creek glacier, the right embankment is much larger than the left. This is especially well marked in the moraines at the ends of Lundy and Leevining Cañons. In all the embankments, excepting those of Rush Creek, a deflection to the northward of the glaciers which built them took place during some portion of their history. In some instances, as already stated, this was caused by terminal moraines which were more massive on the southern than on the northern side of the trough through which the glaciers re-advanced after having retreated.

In the Leevining Cañon embankment the right lateral is probably more than a thousand times larger than the left, and shows many periods of growth. The most marked deflection that occurred when the Mono basin glaciers left their cañons is recorded by the moraines at the mouth of Lundy Cañon. Here, again, the right embankment is far larger than the left and in the writer's opinion caused the glacier that built it to bend abruptly northward as soon as it was free from the cañon walls.

In an article on the meridional deflection of ice-streams[1] W J McGee has advanced the hypothesis that the northward deflection of the eastward flowing glaciers of the Mono basin was caused by the radiant energy of the sun. The deflection is attributed to a more rapid flow of the southern borders of the ice streams, owing to greater mobility on that side, due to greater exposure to the sun's rays. To quote the words of the author: "Let an ice-stream flowing east or west on a meridionally horizontal plain in north latitude 45° have a cross-section bounded above by the transverse semi-circumference of an ellipse whose axes are 2 and 1 respectively, and let the sun be over the equator. The proportion of solar rays directly reaching the south and north halves respectively will then vary as *a-b* to *b-c*," as shown in the following figure,[2] which has been copied from that article referred to.

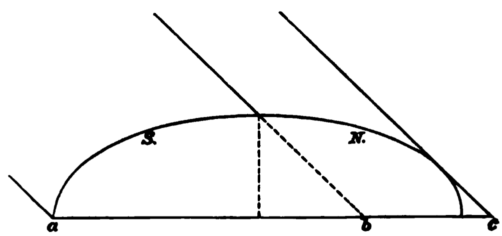


FIG. 8. Hypothetical cross profile of a glacier.

After allowing for certain secondary considerations, which need not be enumerated here, the conclusion is reached that the motion

[1] Am. Jour. Sci.. 3d series, vol. 29, 1885, pp. 386–392.

[2] This figure can not be accepted as even an approximation to the actual profiles of living glaciers.

MORAINAL EMBANKMENTS AT THE MOUTH OF BLOODY CAÑON, FROM THE BASE OF WILLIAMS BUTTE.
From a photograph.

of a point near the southern border of a glacier flowing east or west will be to the motion of a point similarly situated near the northern border of the same glacier in the proportion of 23,660 to 19,433, thus giving a somewhat more rapid flow to the southern border of the glacier. The effect of such differential flow on a glacier 1,000 feet broad is estimated to be a curvature of its course through an arc with a radius of about one mile. This hypothesis was familiar to the present writer while studying the glacial deposits of the Mono basin; but, although it probably contains a germ of truth, facts to sustain it were not found. It seems advisable, therefore, to state definitely the observations and considerations leading to its rejection.

If the Mono glaciers were deflected by energy emanating from the sun, it is evident that the solar influence would have been felt during the first as well as during the subsequent advances of the ice-streams. The records show, however, that the Bloody Cañon glacier, at the time of its first prolongation into Mono Valley, when its path was entirely unobstructed by previously formed moraines, curved southward instead of northward. This is well shown on Pl. XXXV. The same is also true of the Gibbs Cañon glacier, and in a less well-defined manner in the case of the Parker Cañon glacier.

During the later advances of the glaciers of Bloody and Parker Canons the ice, although probably thicker than during the previous period, was confined, for more than a mile in each case, by the previously formed embankments and was then turned sharply northward. Solar influence, if potent at all in deflecting glaciers, must be considered as acting slowly and continuously, and therefore could not have produced the abrupt changes in the courses of glaciers several hundred feet in thickness, as was the case in the examples cited above.

After its first abrupt deflection the Bloody Cañon glacier again bent southward, as during its first advance, and deposited the moraines at *a*, Pl. XXXV. It then once more breached its northern wall and, on advancing, once more curved southward, as is shown at the extreme distal end of the morainal deposits represented on the plate referred to. Throughout the history of this glacier, as is evident from the records we have described, there was a tendency to bend southward after entering Mono Valley, whenever its path was free from previously formed moraines, and not controlled, so far as can now be determined, by the slope of the surface on which it advanced. The evidence furnished by the most typical of the morainal embankments of Mono Valley is thus directly opposed to the hypothesis which refers the northward deflection of the ancient glaciers to solar influence.

In describing the moraines at the mouth of Parker Cañon, it was shown that the right lateral embankment formed after the glacier was sharply deflected, as represented at *e* on Pl. XXXV, did not reach across the glacier bed to the left morainal embankment, but ended

midway and left an older terminal moraine partially exposed beneatn it. The obvious conclusion is, as previously stated, that the terminal moraine obstructed the advance of the ice-stream and caused it to change its course.

The Rhone glacier has been cited as an example of an ice-stream with but slight lateral moraines which expands laterally, so as to form a semicircular or fan-shaped ice-foot. In the case of the ancient glaciers of the Mono basin this tendency to lateral expansion was checked, as has been shown, by the presence of morainal embankments. If the tendency of glaciers to expand on debouching on a plain can be checked by the presence of morainal embankments, and their flow directed so as to maintain their previous stream-like course for some miles, it follows that marked inequalities in the magnitude and strength of the inclosing embankments may deflect the flowing stream toward the weaker side. These are the conditions that obtained in the Mono basin. If we postulate a case where the glacier on emerging from the mouth of a cañon should have heavy morainal embankments on the south side and none on the north side, it is evident that the glacial ice would expand on the unsupported side so as to form a semi-fan-shaped terminus. In some of the Mono Valley glaciers this condition was approached owing to the very great excess of the southern over the northern morainal embankments. These glaciers did not expand so as to form a semi-fan-shaped terminus, it is true, but they were deflected northward toward the side that had the weaker support.

This matter of the northward deflection of the eastward flowing glaciers of the Mono Valley has received more space than was at first intended; we therefore dismiss it, feeling that the essential facts are recorded in this paper and that from them the reader can form an independent judgment concerning the cause of the curvature of the ancient moraines along the east base of the Sierra Nevada.

The majority of the glaciers of the Mono basin exhibited a tendency to adhere to the northern walls of the cañons through which they flowed before advancing upon the plain, as has already been stated. This is illustrated especially in the morainal embankments of Parker Cañon before they become entirely free from the cliffs near the gateway of the gorge. On the northern side of the lake inclosed by these moraines there is a ledge of rock which was partially buried by the left embankment during the last advance of the ice. This ledge was planed and striated in such a manner as to prove that the ice pressed against it with great force. The southern side of the glacier, opposite the position of this ledge, was unsupported except by the heavy embankment it had formed from its own débris. Facts of a similar character were also observed in the records of the neighboring ice-streams which flowed in the same direc-

tion. In all these instances, if the writer's interpretation be correct, the crowding of the glaciers northward was caused by the great size of the moraines deposited along their right or southern margins.

The reason for the large size of the right morainal embankments, as compared with their companions, in the case of the eastward flowing glaciers of the Mono basin, and also the explanation of the massiveness of the terminal moraines on the south side of the troughs in which they occur, is to be found in the fact that nearly all the secondary glaciers tributary to the main ice-stream came from the right, i. e., from the southern side of the gorges they occupied. During the glacial epoch, as at the present day, the greatest accumulation of snow took place on the shaded sides of the cañons.[1] This indicates that the glacial winter had its days of sunshine. The succession of the seasons during the glacial epoch was probably as well marked and possibly even more strongly defined than at present.

The space between the various pairs of morainal embankments in Mono Valley is usually filled to some extent with débris deposited as the glaciers retreated, but seldom enough to destroy the rounded contour of the bottom, except where meadows have been formed. In several instances the glacial trough is divided by terminal moraines into basins, some of which hold lakes. In others the terminal moraines have been deeply cut by the present streams, and the lakes they once held drained to their bottoms. Where this has occurred we find, above the moraine, a grassy meadow through which a willow-fringed brook meanders. The softness and beauty of these sunny retreats are rendered all the more fascinating by the sternness of the rugged peaks filling the sky above them. The walls of débris inclosing these natural meadows are frequently clothed with noble pine or have their ruggedness concealed by the feathery sprays of the mountain mahogany. The traveler in the High Sierra can find no more welcome spot to recruit his strength after the toil of mountain climbing than these inviting camp-grounds afford.

In describing the morainal embankments on the southern shore of Lake Tahoe, which are of the same type as those in the Mono basin, Joseph LeConte has called attention to the fact that the ancient glaciers which built them did not spread laterally on leaving the cañons through which they descended and did not deposit terminal moraines at the ends of their embankments.[2] The hypothesis proposed by Le Conte in explanation of these observations is that the glaciers advanced into a lake on entering the valley, and that their extremities

[1] It is well known that the rocks forming the sides of railroad cuts that run east and west disintegrate most rapidly on the south side; this same tendency may be observed in cañon walls. In case an east and west cañon was occupied by a glacier the greatest load of débris would accumulate on the southern border of the ice, even if there were no ice-streams tributary to the trunk glacier.

[2] On some of the Ancient Glaciers of the Sierra Nevada. Am. Jour. Sci., 3d series, vol. 10, 1875, pp. 126–139.

were broken off and formed icebergs which floated away the débris that under other conditions would have been deposited as terminal moraines. It is thought that the glaciers did not expand on advancing into the valley because they found lateral support in the waters they entered.

The former extent of Lake Tahoe has not been determined, and it is impossible to decide from the evidence reported whether the glaciers entered a lake or not. In the Mono basin, however, the relation of the ancient lake to the glaciers is well known. Some of the glaciers reached a short distance below the highest level of the former lake, as already described, but we have proof that the greatest extension of the ice preceded the maximum rise of the water. In no instance, therefore, could the long, narrow form of the lower portions of the glaciers of this basin be accounted for on the hypothesis proposed by Le Conte. Moreover, in the case of the Parker Creek moraines we have the same type of morainal deposits as in the other instances, but the ice stream which built them did not descend to the upper limit of the ancient lake. Hence we conclude that neither the narrow tongue-like form of the glaciers nor the want of terminal moraines at the extremities of the embankments they deposited can be accounted for by the assumption that the glaciers entered a lake.

If the writer's determinations are correct, the reason why the glaciers of the Tahoe basin did not expand on leaving the cañons through which they flowed was because they were retained by walls formed by the débris carried on their sides. The lateral moraines, and consequently the morainal embankments, were unusually large in comparison with the size of the ice-streams that transported them, and they still far exceed the accompanying terminals in magnitude. The absence of well marked terminals at the extremities of the embankments is due to the facts that the glaciers did not linger at the place of their maximum extension, and that the ice streams were without important branches, and therefore mostly free from medial moraines.

POLISHED AND STRIATED SURFACES.

Rock surfaces may be seen throughout the higher portions of the cañons of the Mono basin which still retain the polish imparted to them by the ancient glaciers. The surfaces of quartzites, granites, and metamorphosed sediments are alike glaciated, and are frequently worn into rounded bosses and swelling domes. Not only are these surfaces so brilliantly polished that they glitter in the sunlight, but they are crossed by striations and grooves in the manner well known in all glaciated regions.

Besides the striations we have mentioned, the polished surfaces of granite and quartzite, in particular, frequently present a series of

concave or nearly semi-circular cracks, from a fraction of an inch to six or eight inches in length, occurring one after another at intervals varying from a fraction of an inch to six or eight inches. The concave side of the cracks in all cases is turned in the direction toward which the ice flowed, i. e., they are convex up stream. Similar crescent-shaped cracks may be seen in the bottoms of the deep grooves made by stones set in the bottom of a glacier; these are also concave in the direction of flow, and sometimes enable an observer to tell the direction of the ice movement when only a small area of rock surface is exposed. These peculiar markings, it seems reasonable to suppose, were caused by a vibration of stones and pebbles as they were forced along under great pressure by the movement of the ice in which they were embedded.

Glaciated bowlders are not common in the moraines of the Mono basin; in fact, one may search for hours without finding a stone that bears evidence of glacial polish or striation. This is the more remarkable as the troughs formed by the morainal embankments still retain the form imparted to them by the ice and must have been subjected to the friction of the glaciers that once flowed through them. The rarity of glaciated bowlders is characteristic of all the moraines of the region we are considering, and indicates that by far the greater portion of the débris deposited by the ancient glaciers was carried on their surfaces. The scarcity of glacial markings on the bowlders composing the moraines may be due in part to a decay of their surfaces since they reached their present position. Although exfoliation has occurred in some instances, it does not seem possible that this could be the reason for the general absence of markings, especially when we remember that the rock surfaces over which the glaciers passed retain their inscriptions with remarkable fidelity.

PERCHED BOWLDERS.

A common feature of the glaciated cañons, as well as of the moraines of the High Sierra, is the presence of bowlders, sometimes of great size, perched in precarious positions on slopes and crests. The most striking example of this nature, and the only one to which it seems desirable to call special attention, is represented on Pl. XXXVIII. This bowlder stands near the eastern shore of June Lake, where the ice was formerly over fifteen hundred feet thick. It is of granite and measures 18 by 28 by 30 feet, and is perched on a granite crag of different lithological character, the top of which is rounded and striated, showing that it offered stubborn resistance to the ice which once flowed over it. The bowlder rests on two prominences of its pedestal and must have been lowered gently into its present position as the glacier which formerly sustained it melted away.

GLACIAL LAKES.

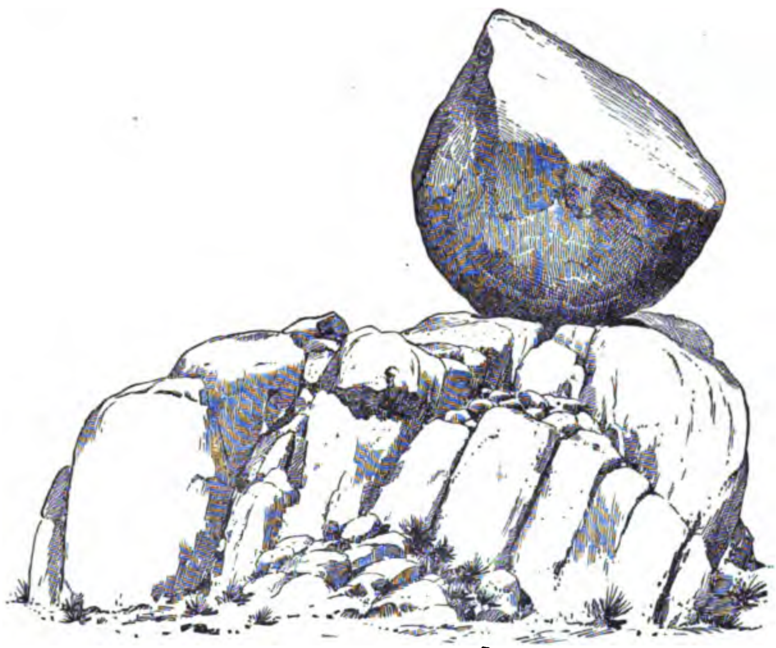
Lakes resulting from glacial action may be grouped into two classes, (1) those occupying rock basins, and (2) those retained by moraines. In the Mono basin there are abundant illustrations of each of these classes. An observer standing on any of the more prominent peaks of the High Sierra may see gem-like lakes by the score in the cañons and valleys below him. It is manifest at a glance that these lakes are confined to the region formerly occupied by ice. In many of the cirques in which the ancient glaciers had their birth there are depressions holding water, and in every cañon and valley and occasionally on broad rocky plateaus, other tarns of a similar character may be seen.

On examining the numerous lakes more critically one finds that many of them occupy depressions in morainal débris or are confined by terminal moraines. In numerous instances, however, as in Bloody and Gibbs Cañons, at the head of Rush Creek, and all about Mt. Lyell and Mt. Ritter, the fact that the lakes occupy depressions in solid rock is beyond all question. One may walk entirely around many of them without stepping off rock in place.

Nearly all the lakes in the Mono basin have been sounded, and the maximum depths of a few of them is recorded on the map forming Pl. XVII. The deepest of the rock-basin lakes is situated in Bloody Cañon, and has a depth of 51 feet.

The lower lakes on the western side of the Mono basin are nearly all confined by accumulations of débris. Those at a higher elevation among the mountains more commonly occupy basins of excavation than of obstruction. The results of these two processes, however, are frequently united. Some of the lower lakes are not confined by terminal moraines, but occupy depressions in the general filling of débris occurring in the bottoms of the cañons near where they open out into the plain. In such instances the depression was apparently filled by an ice-body which lingered long after the supply from the névé fields had ceased. At the site of June Lake, for example, the water resulting from the last melting of the Rush Creek glacier did not flow northward in the direction that would seem to afford the most ready escape, but went southward through the channel now occupied by Reverse Creek. The peculiar drainage at this locality appears to indicate that June Lake was filled by a detached ice-mass after glacial motion had ceased.

The rock basin in Bloody Cañon, described in the introduction, may be taken as the type of a majority of the higher lakes throughout the glaciated portion of the sierra. Other examples might be enumerated, but the geologist who visits the region will have no difficulty in finding abundant illustrations of the phenomena to which attention has been directed.



PERCHED BOWLDER NEAR JUNE LAKE.
Size of bowlder. 30 x 22 x 18 feet. From a photograph.

That the rock basins in the High Sierra were excavated by glaciers the writer finds no reason whatever to question. They frequently occur at the lower limit of a steep slope, which is polished and grooved and bears every indication of having been abraded by glacial action. In such cases the slope and the direction of the furrows show that ice once descended into the basin. On examining the opposite portion of the rim of the depression, glacial markings of the same character will be found. The proof is thus positive that the ice descended into the depressions now filled with water and emerged from them again to continue its course. As there is no other agent known capable of eroding hollows in solid rock having the character of the basins observed in the High Sierra, it seems evident that the theory of the formation of rock basins proposed by A. C. Ramsay, from evidence obtained in Scotland and Switzerland, is substantially correct and furnishes the true explanation of the origin of the examples before us.[1] The manner in which the power of moving ice is directed so as to erode depressions may be open to discussion, but the conclusion that rock basins are a result of glacial action is now too strongly supported by facts to be questioned.

RELATION OF THE GLACIERS TO THE QUATERNARY LAKE OF MONO VALLEY.

The topographic relation between the ancient glaciers of the Mono basin and the Quaternary lake which occupied the lower portion of the same depression may be seen on the map, Pl. XXIX. As there indicated, four of the glaciers extended a short distance below the highest of the terraces formed by the ancient lake. The record of the maximum rise of the lake is a cut terrace moderately well defined and traceable on both the exterior and the interior of the morainal embankments at the end of Lundy, Leevining, and Bloody Cañons. The moraines at the end of Rush Creek Cañon likewise have obscure beach lines about their extremities. The buried moraines at the end of the main Rush Creek terminals are also below the highest recorded level of the lake. Well defined deltas were formed between the extremities of the morainal embankments at the mouths of Lundy and Leevining Cañons. The proof that the highest stage of the lake followed the maximum extension of the glaciers is thus abundant.

The climatic change which causes glaciers to retreat is considered by most geologists to be a rise of temperature, such rise causing the ice to melt more rapidly than the snow fall over the névé region can supply the waste; other geologists are of the opinion that decreased precipitation is the most important factor, the glaciers retreating on account of a decrease of snow supply. If we ascribe the retreat

[1] On the Glacial Origin of Certain Lakes, etc. Quart. Jour. Geol. Soc., London, vol. 18, 1862, pp. 185–204.

of the glaciers of the Mono basin to either of the above causes, it is evident that the inclosed lake into which they drained would also be affected.

If the glaciers retreated on account of an increase of temperature, the accelerated melting of the ice would swell the glacial streams and cause the lake to rise; at the same time evaporation from the lake surface would be increased. The oscillation of the lake would depend, therefore, on the balance of these two opposing forces. If the glaciers retreated on account of decreased precipitation over the névé region, this alone, providing there was no change of temperature, would not immediately affect the lake below, as the melting of the glacier would continue at a nearly uniform rate for some time at least. A decrease of precipitation, however, would, under the present adjustment of climatic conditions, probably be accompanied by a fall of temperature which would exert its influence on the evaporation from the lake and thus tend to produce fluctuations in the lake surface. This brief and imperfect analysis simply illustrates the fact that climatic changes are exceedingly complicated, and that if we seek to trace out minute details in the reaction of the various elements on each other without careful study of meteorological data we may be led far afield.

It is conceded, however, by most geologists, that the controlling climatic influence which allows glaciers to increase until they overrun half a continent, or stems their seemingly irresistible march and causes them to depart whence they came, is temperature. In the case of the glaciers of the Mono basin, a rise of temperature would melt the ice and decrease their length. This would flood the glacial streams, as stated above, and cause the inclosed lake to which they were tributary to rise. Such a climatic change would also increase evaporation on the lake surface and tend to lower the lake. But during the earlier portion of this change the melting of the snow and ice on the mountains must have been relatively greater than the increase of evaporation; hence the lake experienced a temporary rise and recorded its maximum elevation on the previously formed morainal embankments.

An oscillation of Lake Mono similar to that which followed the melting of the Quaternary glaciers may be witnessed every spring when the melting snows of the mountains cause the lake to expand, while the increased evaporation felt throughout the summer causes an oscillation in the opposite direction.

There are no large bowlders in the Mono basin at a distance from well-defined moraines to suggest that icebergs were formed in the Quaternary lake. Neither are there any sections of lacustral strata divided by glacial deposits, as would have been the case had icebergs freighted with morainal material floated on the ancient lake. But the presence of heavy beds of gravel adjacent to the foot of the

mountains indicates that there was an inter-lacustral period of desiccation, during which shore gravels were carried out over the previously deposited lake beds, and these may reasonably be correlated with the main period of glacial retreat recorded by the moraines.

The two best defined advances of the Sierra Nevada glaciers and the two high water stages of the Quaternary lake of Mono Valley are believed to correspond in time with the two high water stages of Lakes Bonneville and Lahontan.

VOLCANIC HISTORY.

In traversing the region represented on the accompanying map of Mono Valley (Pl. XVII) one is impressed with the fact that nearly all the country to the east of the Sierra Nevada is formed of volcanic rocks, among which basalts, andesites, and rhyolites abound. At the base of the Sierra, in the neighborhood of Lake Mono, there are scores of recent craters of basalt, andesite, and more acid lavas; somewhat farther removed are mountain ranges composed very largely of more ancient volcanic rocks, but which owe their present form to erosion rather than extravasation. In the Sierra, however, at least in the neighborhood of Lake Mono, no recent volcanic rocks occur. The most conspicuous intrusive rock to be seen in this portion of the mountains is a light-colored granite which penetrates slates, quartzites, and limestones. The great mass of the range is composed of granite.[1]

The observations of the writer coincide with the conclusions of previous observers, and indicate that the eastern face of the Sierra Nevada is at many points the boundary between the volcanic areas so common in the Great Basin and the granites, quartzites, slates, etc., to the west.

The older volcanic history of the region surrounding Lake Mono would be an interesting study, but it falls outside the scope of the present investigation. We shall attempt here to describe those volcanic phenomena of the Mono basin which are so recent that they may be considered of post-Quaternary or Quaternary date.

RECENT VOLCANIC PHENOMENA.

The evidence of late volcanic activity in Mono Valley is furnished by craters and lava flows which are more recent than the former high water stage of the lake and were formed after the last recession of the Sierra Nevada glaciers. There are also feeble fumaroles and springs of heated water, which perhaps indicate that the volcanic energy so recently active is yet slumbering beneath the surface.

[1] A distant view of the unexplored region south of Mt. Ritter suggested that there have been recent eruptions in that portion of the crest of the range; but our observations in this connection are too indefinite to have much weight.

FUMAROLES AND HOT SPRINGS.

The only locality where fumaroles now occur within the Mono basin is at Hot Spring Cove, on the eastern side of Paoha Island. On the steep bluff forming the northern shore of the cove there are openings in the rocks through which steam escapes with some violence, and is accompanied by a slight deposition of ferric chloride. The temperature at the mouth of the principal orifice is 150° F. The evidence of subterranean heat at this point has been observed by J. D. Whitney, who considers the locality a veritable fumarole.[1] It may be, however, that the openings through which the heated vapor escapes are in communication with the hot spring at the margin of the lake near at hand, and are therefore not of the nature of fumaroles as the term is usually understood. At times columns of steam hundreds of feet in height have been seen to escape from these orifices, but usually the ascending vapors can not be distinguished by an observer on the mainland except in clear, cold weather.

The hot springs of the region have already received attention in connection with the lacustral history of the basin, with which some of them are intimately connected (pages 287–292). Although they are closely associated with volcanic rocks of recent date, it is not clear that they derive their heat from that source. Many hot springs throughout the Great Basin are known to occur near lines of displacement that exhibit evidence of recent movement, and they are believed to owe their high temperature in many instances to the heat produced by the friction of the rocks along the plane of faulting. It is also possible that springs may arise from such a depth that their temperature is determined by the general internal heat of the earth. It is evident, therefore, that hot springs alone can not be considered as proof of recent volcanic activity.

MODERN CRATERS AND LAVA FLOWS.

There are a number of craters in the Mono basin of more recent date than the high water stage of the lake which followed the maximum extension of the Sierra Nevada glaciers. Some of these points of recent eruption are situated on the islands of the lake, others occur beneath the lake surface, and still others are to be found on the southern portion of the basin, where they form a part of the beautiful range of volcanic cones known as the Mono Craters.

In the following sketch the topography of the northern end of Paoha Island is represented. Each of the bowl-shaped depressions shown near the water's edge is a crater of lapilli, which was formed after the lake had fallen at least as low as at the present time. These craters do not contain lacustral sediments, and are not scored with

[1] Geol. Survey of California, Geology, vol. 1, 1865, p. 453.

beach lines on their outer slopes. The loose, incoherent nature of the material of which they are composed renders it evident that they could not have withstood the action of waves and currents for even a brief period without having evidence of the fact inscribed upon them. One of the craters in this group is submerged beneath the waters of the lake, as may be seen from the bluff near at hand. The presence of another, a few rods from the shore, was indicated by soundings. The largest crater shown in the sketch is from one hundred and fifty to one hundred and seventy-five feet deep. The regularity of its outlines has been broken by the formation of two smaller craters on its rim. The narrow ridge of lapilli separating the main crater from its larger parasite forms a symmetric curve as

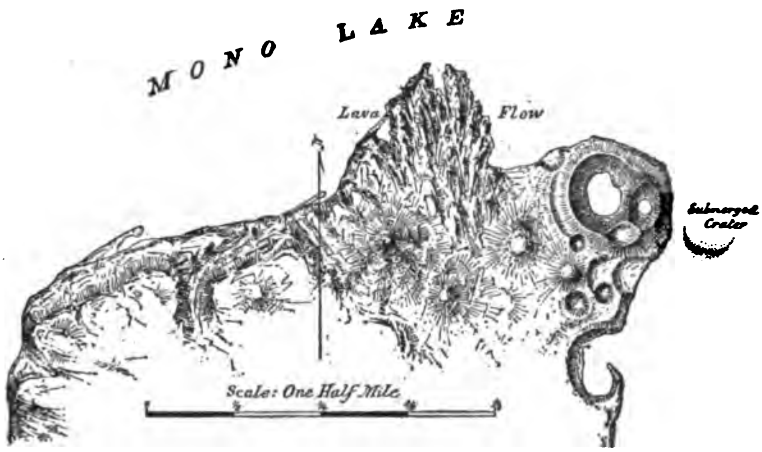


FIG. 10.—North end of Paoha Island.

it descends one side and ascends the opposite slope. The craters parted by this low divide hold lakelets of strongly alkaline water at the same level as the water of the surrounding lake, from which they are supplied by percolation. The waves of Lake Mono have carved away the outer slopes of the craters and will no doubt soon open a breach into their interiors. In fact, under the present conditions, the waves and currents are destined, at no very distant date, to remove the crater walls and fill up the depressions they inclose. The crater farthest south in the series has already been broken by the waves and forms a sheltered cove in which small boats may take refuge.

The surface of the island for a distance of half a mile from these points of eruption is thickly strewn with lapilli and with basalt-like masses, identical with the material of which the craters are composed. These ejected fragments rest upon lacustral marls and prove that a volcanic eruption of considerable violence was one of the latest events in the history of the island.

On the west side of the craters shown in Fig. 10 there is a coulée

which descends into the lake. That this lava stream was formed at a recent date is at once suggested by the fresh appearance of the black, angular blocks composing it. The lava is not covered with lacustral sediments and is without deposits of calcareous tufa; it is therefore certainly more recent than the last high-water stage of the lake. It is also of later date than the lapilli craters near at hand, as its surface is entirely free from the débris showered on the island when the craters were formed. The coulée descends into the lake without change of character, thus indicating that the surface of the water at the time of its formation may have been lower than now. The distinction, however, between a sublacustral and a subaërial lava flow is not sufficiently well determined to allow us to decide in every case in which manner an eruption occurred.

The central portion of the coulée is lower than the sides. After the sides and surface had been cooled the still liquid interior flowed out and allowed the surface crust to subside. In looking down on the trough thus formed it will be noticed that the apparent chaos of rocks composing it is in reality not without some order. The huge angular blocks are heaped in curved ridges, convex in the direction of flow and concentric one with another, suggesting a similarity in form to small terminal moraines deposited at the end of a retreating glacier. This wave-like appearance is apparently due to pulsations in the flow of the stream of molten rock.

The material composing this coulée, as determined by J. P. Iddings, is essentially a hypersthene andesite, but the structure of the rock, as seen under the microscope, is indefinite. Individual crystals of the various minerals composing it are poorly defined, rendering its petrographic relations somewhat doubtful. It is on the dividing line between andesites and basalts, but apparently the weight of evidence places it among the former. It is a black, fine-grained, compact rock, breaking with a conchoidal fracture. To the field geologist it has all the appearance of basalt, excepting that it is free from olivine. The position of the orifice from which the lava issued is indefinite, but it appears to have broken out at the base of some conical hills of volcanic origin of older date than the lapilli craters at the lake margin. This overflow is certainly the last volcanic eruption that occurred on Paoha Island, and its lava is one of the most recent rocks, if not the very latest rock, of igneous origin formed in the valley.

The rock of the high spur forming the northern shore of Hot Spring Cove is also basic in character, but its precise nature, whether basalt or andesite, has not been determined. As it is buried beneath a heavy deposit of light-colored lacustral marls it is evidently not of very recent origin.

The bluffs on the western border of the island are composed of mica andesite, which appears under two quite distinct aspects; one

an obsidian, the other a compact, gray, stony mass with a somewhat granular instead of a glassy texture. Both chemically and mineralogically these varieties are identical. Their striking contrast in general appearance is apparently due to difference in rate of cooling. The glassy variety sometimes forms bluffs from thirty to fifty feet high, in which a columnar structure is plainly distinguishable. Resting on the andesite are beds of fine lacustral marl, showing that this outflow preceded the last high-water stage of the lake. The surface of the vitreous andesite frequently presents a beautiful iridescence, similar to that on ancient glass vases that have long been buried, and probably due to similar causes.

Negit Island always appears black and forbidding when seen from a distance. It is without lacustral deposits and was formed subsequent to the last high-water stage of the lake. Its recent origin is also indicated by the absence of a submerged terrace like that surrounding the larger island. This is well shown by the sublacustral contours on the map forming Pl. XIX. A thin coating of calcareous tufa occurs about its base and sheathes the rocks up to a height of about twenty feet above the present lake surface. The crags on which it was deposited are therefore less recent than the lava flow at the northern end of Paoha Island, which is entirely free from tufa.

Negit Island is composed of a crater and a lava coulée. The rock here extruded has been classed by Mr. Iddings as hypersthene andesite, but it is even more basaltic in appearance than the similar rock forming the lava stream on Paoha Island, and might be characterized as intermediate between andesite and basalt. The crater is unlike any other in the lake basin; it is not a lapilli cone, but is composed principally of scoriæ, which were ejected in huge, semi-plastic masses.

The small islands and crags dotting the surface of the lake north of the two principal islands are remnants of an ancient volcanic overflow which has been mostly removed by erosion. The rock forming many of these crags agrees both in appearance and structure with the mica andesite underlying the lacustral marls of Paoha Island, and its widely separated fragments indicate that a body of lava of quite uniform character must have formerly occupied a considerable area where Mono Lake is situated. The cluster of small islands now remaining adds greatly to the picturesque character of the lake.

Other volcanic deposits more recent than the high-water stage of the Quaternary lake are to be found in the Mono Craters, the magnificent range of lapilli cones represented on Pl. XXXIX. The crater at the extreme northern end of this range and nearest to the lake is a bowl of lapilli with crags of rhyolitic obsidian and pumice rising within. It is situated below the level of the highest beach line on the borders of the valley, but does not bear marks of wave action on its sides and is not coated with sedimentary deposits. Owing to

the incoherent character of the material of which the crater is composed, it could never have been within the reach of the lake water without losing the symmetry of its form, and we are thus assured beyond question that it was built after the recession of the waters which formerly flooded the basin. Adjoining it on the northeast is another bowl-shaped crater of lapilli, depressed below the general surface, which is older that the crater described above, but probably younger than the Quaternary lake.

No beach lines can be distinguished on the northern end of the main mass of the Mono Craters at the horizon where they should be expected had the volcanoes attained their present form before the last flooding of the valley. The lowest crater in this portion of the range is a deep, bowl-shaped depression, encircled by a symmetric rim, which was apparently formed during one of the most recent eruptions in the basin. Its outer slope is not scored with beach lines, and we conclude that it is of post-Quaternary date. The great obsidian eruption at the northern end of the range, named the Northern Coulée on Pl. XL, is also believed to be very recent, not only because its base is not scored with beach lines, but for the reason that its surface is fresh in appearance and corresponds in many ways with the similar lava flow at the southern end of the range, which we know to be of post-Quaternary date.

That the coulée at the southern end of the craters was formed after the maximum extension of the Sierra Nevada glaciers is proved by the fact that on reaching the base of the cones it entered a depression previously occupied by the most easterly branch of the Rush Creek glacier. The glacial and volcanic records here overlap, and the latter are the more recent. The character of the lavas extruded from the Mono Craters will be described a few pages in advance, when the reader has made the acquaintance of the cones from which they originated.

Volcanic rocks of post-glacial date appear in the bed of the Rush Creek glacier, as already noticed on page 345. These are rough, angular crags of black basalt that were forced through the morainal débris filling the bottom of the depression.

A basaltic crater which stood directly in the path of the Rush Creek glacier, and was partially removed by it, has already been described.

The only remaining evidence of the recency of volcanic activity about Lake Mono observed by the writer is furnished by superficial deposits of lapilli, which not only cover large portions of the valley and are strewn over the eastern slope of the neighboring mountains, but may be found on the surface of moraines deposited by the Quaternary glaciers. These accumulations are most abundant about Rush Creek, but may also be seen on glacial deposits more remote from the Mono Craters.

South of Reversed Creek, on the divide between the San Joaquin and Owen's Rivers, are immense accumulations of light, pumiceous lapilli, which were probably derived from some point of eruption near at hand. These deposits are outside of our present field of study and the crater from which they originated was not discovered.

From the evidence presented in the last few pages it will be seen that volcanic outbursts of a most interesting and varied character have occurred in the Mono basin at a very recent date. Not less than ten, and probably fifteen, craters have been formed in and about the lake since its last great expansion and after the glaciers of the Sierra Nevada had begun their final retreat. Both the northern and southern extremities of the Mono Craters were formed in post-Quaternary times. This is the greatest change that has been wrought in the topography of the basin since the evaporation of the ancient lake.

The freshness of the lava coulées and the perfection of the lapilli craters indicate that the eruptions to which they owe their origin were very recent, but we have no means of determining their age in years. So far as the writer has been able to learn, the traditions of the aborigines of the region are silent concerning them. Among the most recent craters are those on Paoha Island and the one on the south shore of the lake, shown to the extreme left on Pl. XXXIX.[1] In each of these instances aged cedars and pines are growing within the bowl formed by the violently ejected lapilli, thus proving that the craters could not have been the site of an eruption within at least one hundred years. A more exact limit can not be drawn from the facts observed. The pine forests surrounding the Mono Craters on the east and south are growing in immense fields of loose, light-colored lapilli, but whether the trees are rooted in the lapilli or in a buried stratum of soil was not determined.

QUATERNARY VOLCANIC PHENOMENA.

The craters and lava flows described below are mostly older than the last high-water stage of the Quaternary lake of the Mono basin, yet are so fresh in appearance and have suffered so little from atmospheric action that it is evident they can not be of great antiquity. They belong to a series of events which terminated in post-Quaternary time and are evidently somewhat older pages of the same history. In some instances we have been able to connect the volcanic eruption directly with the deposits of the Quaternary lake, but in others the craters are so far distant from lacustral records that it is impossible to determine their geologic position with accuracy. Some which we have considered as Quaternary may in reality be of the same age as those we have proven to be more recent than the glacial epoch.

[1] Another view of this crater is given on Pl. XLI, and its position is shown in Pl. XL.

By far the grandest display of Quaternary and post-Quaternary volcanic action within the Mono basin is furnished by the Mono Craters.

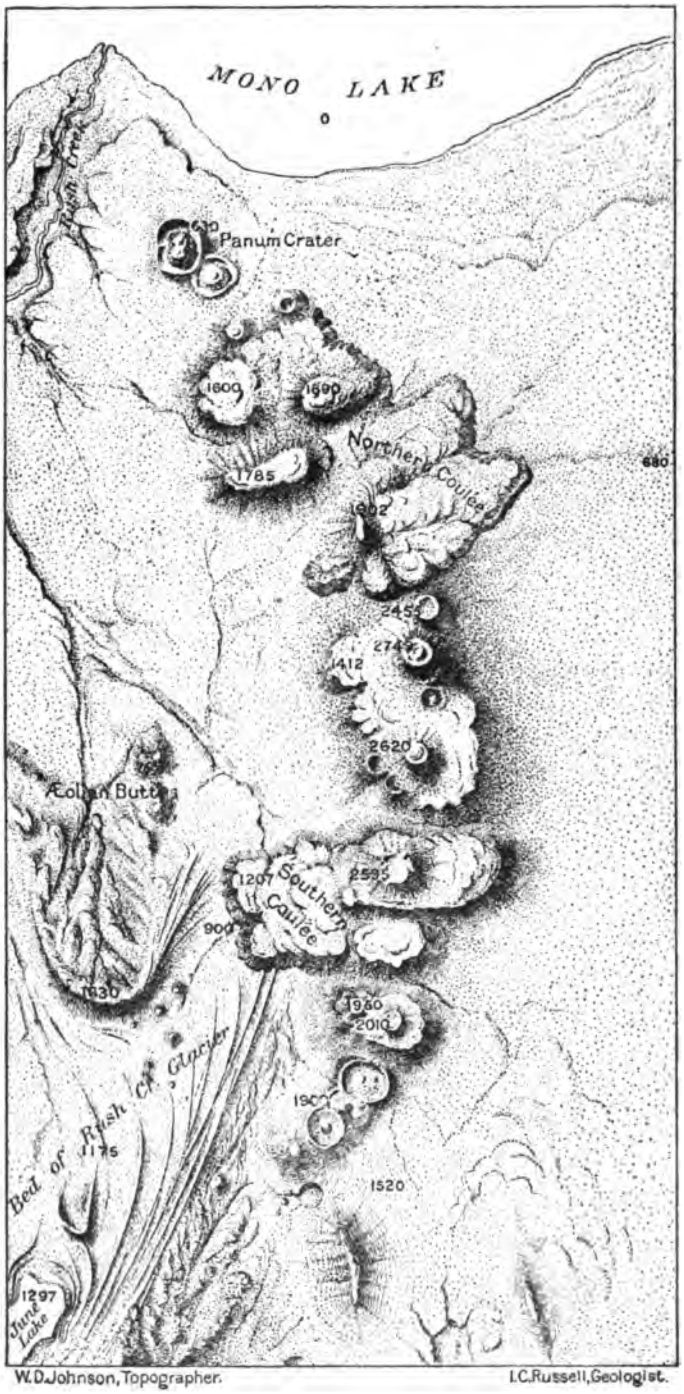
THE MONO CRATERS.

I have given this name to the slightly crescent-shaped range of volcanic cones which commences at the southern margin of Lake Mono and extends about ten miles southward. The attention of every one who enters Mono Valley is at once attracted by the soft, pleasing colors of these craters as well as by the symmetry and beauty of their forms. They are exceptional features in the scenery of the region, and are rendered all the more striking by their proximity to the angular peaks and rugged outlines of the High Sierra. The contrast, however, which serves to enhance their beauty tends also to dwarf one's conception of their magnitude. The central cone, crowning the range, rises 2,750 feet above Lake Mono, and has an elevation of 9,480 feet above the level of the sea. The elevation of Vesuvius is about 4,000 feet; the height of Stromboli is a little over 3,000 feet. The larger of the Mono Craters are thus comparable in height with these classic volcanoes of the Mediterranean, but their bases are smaller and their slopes consequently more precipitous. Could this range of craters and lava flows be transported to a region of low relief, as the valley of the Mississippi for instance, it would be far-famed for its magnificent scenery as well as for its geological interest. In its present location it is rendered of secondary importance by the vastly greater mountain range whose crest is barely ten miles distant.

The accompanying illustrations will convey to the reader a much more correct and graphic idea of the topography and general appearance of the volcanic range than any written description; I shall therefore notice their topography and scenic features but briefly.

The Mono Craters are composed entirely of ejected matter. Lapilli (a general name for small rock fragments thrown out by volcanoes) form the most conspicuous portion of the cones. There are also several coulées of volcanic rock which flowed out in a molton condition and consolidated on cooling. These two methods of extrusion have produced striking contrasts in the form and color of various portions of the range.

The lapilli have a light gray tint and form smooth, even slopes about the vents from which they were ejected. All the cones of the range are largely built of this material and are especially beautiful on account of the harmonious tints of the fragments of which they are formed. In contrast with this clastic material are thick sheets of black obsidian that flowed in various directions from vents, usually near the crest of the range. One of these coulées occurs near the southern end of the craters, and another of less magnitude near



MONO CRATERS

0 1 2 3 4 MILES.

Elevation above Lake Mono given in feet.

their northern extremity. On Pl. XL, these are named the southern and northern coulées.

The obsidian overflows are black and angular, and in fact they present the most rugged appearance that can well be imagined. Owing to the viscid character of the lava at the time of its extrusion, it formed thick sheets which terminated on their lower margins in precipices two or three hundred feet high. The contrast here presented by essentially the same rock under different conditions of extrusion can scarcely be surpassed. The lapilli are loose, vesicular, incoherent, and light-colored, and form smooth, curved slopes of great regularity and beauty; the obsidian is compact, dense, black in color, massive in appearance, and on the surface is broken into huge angular blocks thrown together in the utmost confusion.

The range is unlike any other known to the writer, and, so far as can be judged from the reports of explorers, is the only one of its kind in the United States. When the valley in which these craters are situated becomes more familiar to tourists and geologists, they can not fail to be widely known as typical illustrations of mountains formed of acidic lavas.

The geology of the Mono Craters, so far as the surface records are concerned, is simple and adds but little, if anything, to our knowledge of volcanic phenomena in general. What may have been the ultimate cause of the volcanic energy which reared these grand memorials of its power is beyond our limit of vision. The forces here active but yesterday, as the geologist reckons time, were of the same general nature as those exhibited in all existing volcanoes, the origin of which is still an unsolved problem in the physics of the earth.

The oldest rock exposed in the Mono Craters is in the hill which is the nearest point in the range represented on Pl. XXXIX. This is a remnant of an ancient crater. The rock composing it is hornblende andesite and differs from any other outcrop in the range.[1] With the exception mentioned, all the craters and coulées composing the range are of rhyolite, which presents a multitude of variations in color and structure, but throughout the entire series the composition and essential microscopic characters of the rock remain the same. In the coulées, the rhyolite appears as a compact black glass or obsidian, which breaks with a brilliant conchoidal fracture. In thin sections under the microscope this glass is seen to contain numerous microliths or small crystals of hornblende, feldspar, and biotite, and also multitudes of trichites, or incipient crystals that are too incomplete to admit of mineralogic determination. At times the glass has

[1] In a note from J P. Iddings its lithological character is described as follows: "The glassy, microlitic ground mass carries many small porphyritic crystals of reddish brown hornblende and fewer of light brown hypersthene, augite, and reddish brown mica with those of plagioclase feldspar. The hand specimen shows large glassy plagioclase feldspars."

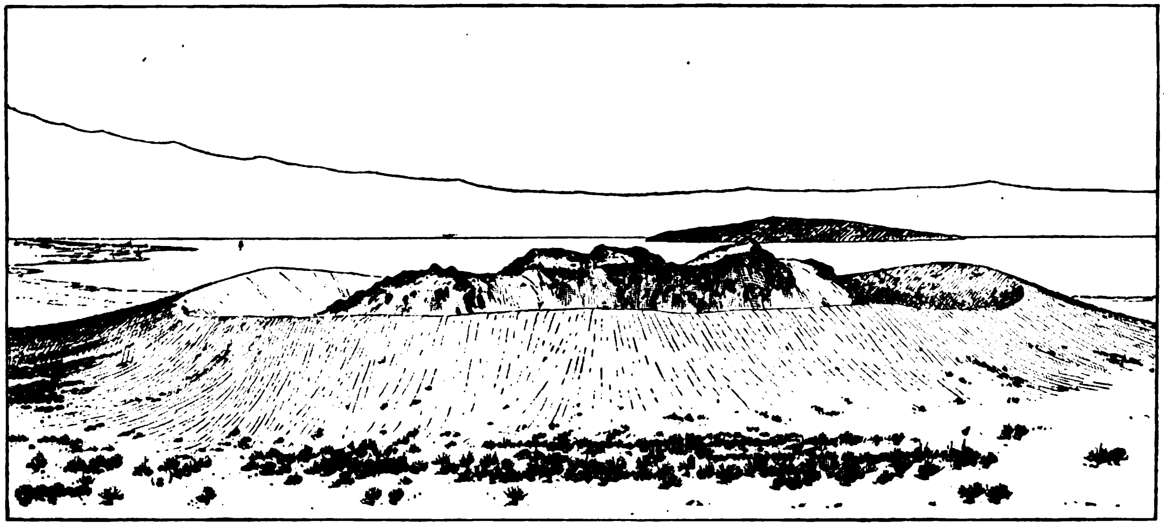
a beautiful banded structure which may be observed both in hand specimens and in large masses. The microscope shows that these bands are formed of microliths arranged in parallel layers. The flow of the glass during its extrusion is plainly indicated by contorted lines, which may be followed through large masses, and sometimes by layers of lapilli which fell as a shower on the surface of the glass while it was yet in a plastic state and became involved in the magma as the semi-fluid mass flowed on. The rock in some places was completely shattered at the time of its eruption. The angular fragments thus produced sank in the still liquid portion and formed a breccia of glass when the mass cooled. Again, the viscid glass was distended by bubbles of steam so as to be scoriaceous. When the bubbles were small and very numerous the mass became froth-like and on cooling formed a nearly white pumice. The cavities of the pumice are frequently elongated, owing to movements of the rock while it was yet plastic. The scoriaceous and pumiceous portions of the rhyolite are most abundant near the surface of the lava streams. Their interiors are apparently compact and massive. As in existing volcanoes, these variations appear to have resulted from difference in pressure. One may easily collect at the ends of the obsidian coulées a suite of specimens which will exhibit a complete transition from compact glass without a bubble to nearly white pumice, so light and frothy that it will float on water.

The chemical composition of a specimen of scoriaceous rhyolite, which may be taken as typical of both the coulées and lapilli so far as their constituents are concerned, is reported by T. M. Chatard as follows:

Analysis of rhyolite.

Constituents.	Per cent.
Loss by ignition (mainly water)	2.20
Silica (SiO_2)	74.05
Alumina (with trace of iron) (Al_2O_3)	13.85
Lime (CaO)	0.90
Magnesia (MgO)	0.07
Potash (K_2O)	4.31
Soda (Na_2O)	4.60
Total	99.98

The fragments forming the lapilli cones are usually small and frequently quite uniform in size over large areas. Commonly they are less than an inch in diameter, but sometimes scoriaceous masses were thrown out that are several cubic feet in size. These fragments are of the same mineralogic character as the obsidian coulées, and are sometimes compact and vitreous; more frequently, however, they are scoriaceous and pumiceous. They are rough and angular and



PANUM CRATER; LAKE MONO AND PAOHA ISLAND IN THE DISTANCE
From a photograph.

bear no indication of having been erupted in a plastic condition, as is frequently the case in craters formed of more basic lavas. They appear to have been cooled rapidly and to have been shattered by the expansion of included vapors as they were brought to the surface, as well as by the violence of the eruption to which they owe their extrusion. The angle of the slope on the interior of the craters is usually greater than that of the exterior, and frequently reaches twenty-five or thirty degrees. The outer slopes of the craters crowning the range have suffered considerably from weathering, but as they remain, their inclination is between twenty and thirty degrees. When the surface is in part of lapilli and in part of compact rock, the angle of slope increases. At the ends of the obsidian coulées it reaches seventy-five or eighty degrees, and at times is actually perpendicular.

As may be seen on the accompanying map of the Mono Craters, there are no less than twenty craters still distinguishable in this range. Othere are undoubtedly buried beneath the more recent deposits. The craters still to be seen may be grouped in two classes, for convenience of description, but in reality they are all of the same type. In the first class nothing but fragmental material was ejected. In such instances the lapilli fell on all sides of the point of eruption and built up symmetric rings inclosing conical depressions. Some of the basins thus formed are depressed bowls, the rims of which are but slightly elevated above the surrounding surface. Others are well defined cones with deep depressions in their tops. In the second class are craters of a similar character which gave egress to molten rock. The craters that were points of eruption for both lapilli and lava may again be divided into two classes: (1) Those in which the lava did not escape from the bowls formed by the eruption of lapilli, and (2) those that were the sources of coulées. As will be seen at a glance, these variations depend simply on the intensity of volcanic activity. In some of the craters the eruptions were carried farther than in others. The first eruption in each instance was a violent ejection of comminuted rhyolite usually scoriaceous, but sometimes compact and glassy. In the crater formed entirely of lapilli the eruption ended at this point. At other times an escape of viscid lava took place through the channel from which the lapilli had been ejected. In some instances when this occurred the lava barely entered the bottom of a crater before it was congealed, and the eruption stopped so far as that individual vent was concerned. An example where the activity was checked at this stage is shown at the southern end of the range (see Pl. XL), and is illustrated in cross-section at *c*, Fig. 11. Another example of the same character is shown in the center of Fig. 13. At other times the molten rock was forced up in the center of the crater until it stood higher than the encircling rim of lapilli, but did not overflow. The type of this

variety of eruption is shown in the crater near the lake margin (Pl. XL). We have named this Panum Crater.[1] This is in reality a double crater, and owes its construction to two separate eruptions, at each of which a rim of lapilli was formed and a protrusion of lava took place. This double crater is in part superimposed upon an older and nearly defaced crater, as may be seen on inspecting Pl. XL. In the craters of which Panum is the type, the rough crags piled in the center of the bowl of lapilli are not of the nature of a cone of eruption, as might be supposed from our knowledge of Vesuvius and other similar volcanoes, but they are ejections of molten rock of the same character as the neighboring lava flows. They are in fact incipient coulées which were congealed before a definite flow in any direction had been established. The rim of lapilli in such instances is unbroken. A cross-section of a crater of this type would present the appearance shown at *d* in the series of diagrams given in Fig. 11.

The small cup on the northern edge of a coulée, at the extreme northern end of the main range, is an exception to the others in the series, as it is largely composed of scoriaceous rhyolite, instead of fragmental material. A cross-section of this crater, as sketched by W. D. Johnson, is shown at *f*, Fig. 11. The sides of the depression are extremely steep and rugged and form a funnel-shaped crater about seventy-five feet deep.

Another crater of scoriaceous rock, a section of which is shown at *e* in the diagram (Fig. 11), occurs near the southern end of the range. The peculiar form of this circular depression is perhaps to be accounted for on the assumption that molten rock rose in a bowl of lapilli and then subsided, leaving the level-floored basin now to be observed.[2]

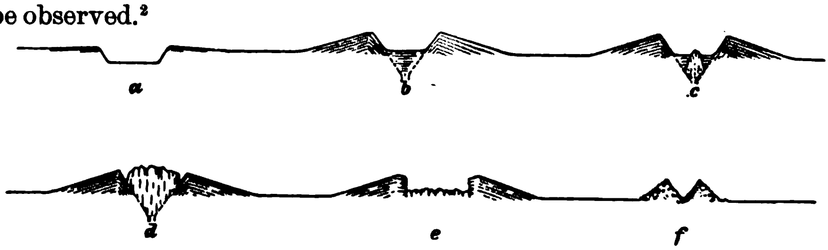


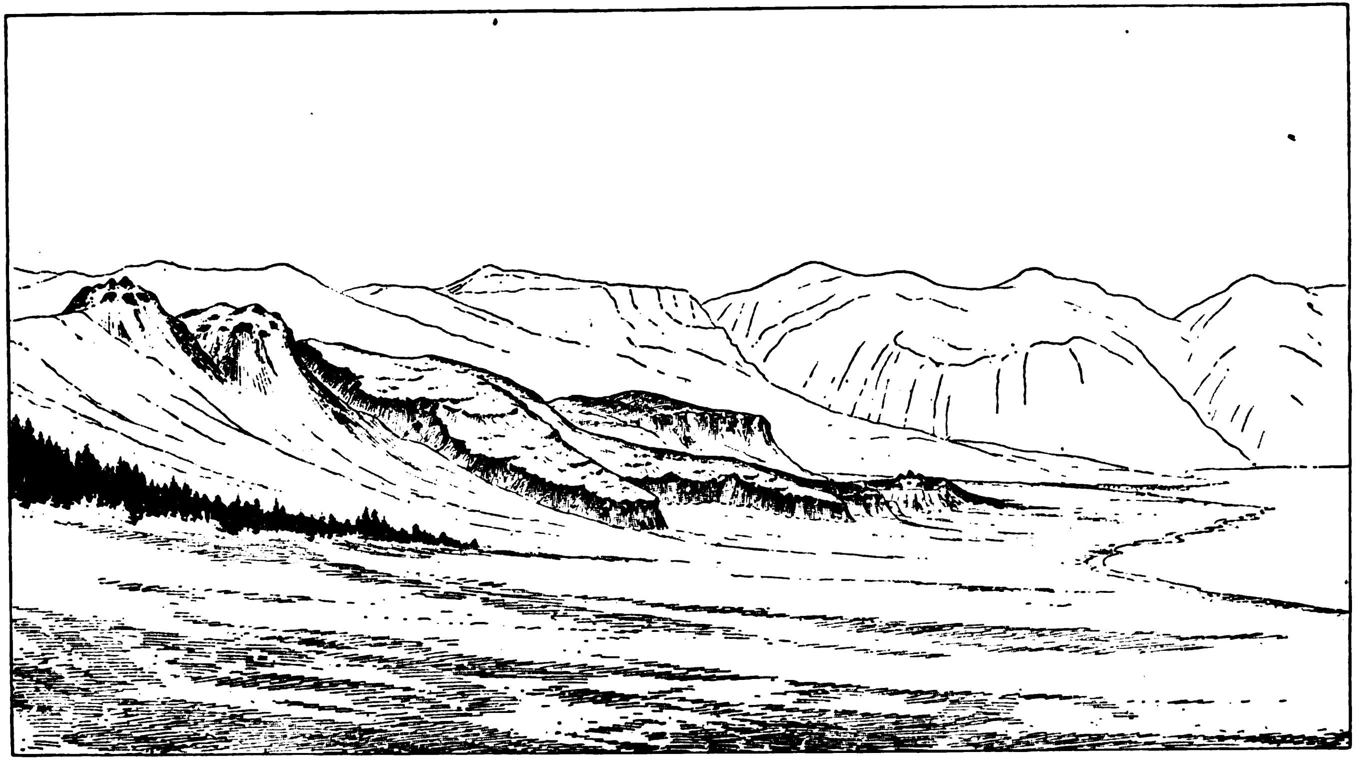
FIG. 11. Cross profiles of some of the Mono Craters.

In the profiles of lapilli cones represented above the internal structure is conjectured from their form and from our knowledge of similar deposits in other regions where sections have been exposed posed by erosion.

The craters in which volcanic action was most energetic gave origin to coulées of lava that overflowed and cut passages through the rims

[1] Pa-num, in the Pa-vi-o-osi language, means a lake.

[2] This crater may be recognized on Pl. XLV. It is the northern one in a series of three of about equal size, situated at the southern end of the range.



OBSIDIAN COULÉE AT NORTH END OF MONO CRATERS.
From a field sketch.

of lapilli in which they originated. Examples of this occur on the crest of the range near both its northern and its southern extremities. One of the smaller flows near the north end of the range may be traced directly to the crater that gave it origin, a portion of the walls of which still remains. In the great overflow at the southern end of the range the crater of lapilli, if such existed, from which the outburst of obsidian took place was obliterated when the volcanic action reached its height. The obsidian was extruded from the vent in a thick, viscid mass, which flowed westward down the mountain side. Another coulée of approximately the same age was extruded from a vent near at hand, or perhaps from the same vent, and flowed eastward.

One of the most striking features illustrated by the lava streams of the Mono Craters is that the molten rock came forth in a viscid or semi-fluid condition and cooled rapidly. The fact that the mass of the lava formed a glass in which crystallization of individual minerals had hardly begun when consolidation took place, attests the rapidity with which cooling occurred. The extruded lava was apparently sufficiently heated to be pasty or semi-fluid, but the temperature was not raised high enough to produce what is usually termed fluidity and thus permit rapid flow.

The extreme ruggedness of the coulées is due to the fact that they hardened at the surface during the time they were still moving. The crust thus formed became broken and involved in the pasty material beneath in a most complicated manner. The steepness of the scarps formed at the ends and sides of the coulées was also due to the viscid condition of the glass composing them. In flowing down the side of the craters the lava descended slopes that must have had an inclination of fifteen or twenty degrees, but only in the case of the greatest eruptions did the viscid streams reach the plain at the foot of the cones. In no instance did they continue their course for a considerable distance after leaving the abrupt slopes. The steepness of the surfaces of the overflows is indicated on Pl. XLII, which is from a sketch of the eastern portion of the northern coulée as seen from the vicinity of the Mono Mills.

Had the lava been more liquid, the ends of the coulées would have been low and would have terminated in an indefinite way without forming scarps; but being viscid and flowing slowly they advanced with a precipitous front, having a height of from two to three hundred feet. Before the edges of the coulées were broken and defaced by weathering, they must have been approximately perpendicular or perhaps overhanging. Even at the present day, after many blocks have fallen and the formation of a talus slope has commenced, the climber finds it extremely difficult to scale these rugged and broken escarpments of glassy fragments. Some of the characteristics we have described may be recognized on Pl. XLIII, which represents the extremity of the southern coulée.

These outbursts of acidic lava are in strong contrast with the overflows of basic rock with which geologists are most familiar. In the eruptions of Vesuvius and other basaltic craters, the coulées are frequently quite liquid at first, flow rapidly, and reach a distance of many miles before congealing sufficiently to check their progress. The small coulée on Paoha Island is more basic than the rhyolites of the Mono Craters, and at the time of its formation was more liquid than were the obsidian coulées described above at the time of their extrusion. Owing to its fluidity, it descended a slope with but a very small angle of inclination, yet did not spread as widely as would be expected had the rock been basalt instead of andesite.

The Mono Craters are grouped in a north and south line, and, from the nature of volcanic eruptions in general, we conclude that they were formed along a fissure, probably a branch of the great Sierra Nevada fault. Disregarding the hill of hornblende andesite, which is older than the craters and coulées composing the main portion of the range, it is evident that the central cones were first built, and that subsequent eruptions took place both to the north and south of the first formed valcanoes. This is indicated not only by the manner in which the cones overplace and intersect each other, but by the amount of weathering that has taken place in different portions of the range. The two central cones (represented on Pl. XLIV) are much wasted as compared with the most recent eruptions and no longer contain depressions in their summits, while those to both the north and the south are perfect in outline and exhibit scarcely a trace of erosion.

The highest beach line formed by the Quaternary lake of Mono Valley may be traced along a portion of the southern base of the Mono Craters and occurs on the side of the hill of hornblende andesite before mentioned, but is absent at the northern end of the range, just at the point where it should be most conspicuous had that portion of the craters been in existence before the high-water stage of the lake.

The evidence is conclusive that a great eruption of lapilli took place where the central portion of the Mono Craters is situated some time previous to the existence of the Quaternary lake. This eruption resulted in the formation of lapilli cones nearly three thousand feet high. Coulées, partially buried by these eruptions, indicate that still earlier portions of the history of the range are now concealed.

The Mono Craters, as we have seen, are in striking contrast with the rugged scenery of the surrounding mountains, and form an independent range that is well defined both topographically and geologically. They occur, however, in a narrow belt of recent volcanic activity that may be traced some distance both north and south. This line of volcanic outflow follows the eastern base of the Sierra Nevada and is intimately associated with the line of faulting which determined

OBSIDIAN COULÉE AT SOUTH END OF MONO CRATERS.

From a photograph.

the trend of the range. The majority of the craters immediately south of the hydrographic rim of the Mono basin and on a line with the Mono Craters are of a dark basaltic lava, very different from the erupted material forming the numerous cones to the northward. There is one exceptional spot, however, just outside the Mono basin, at which craters occur of the same character as those in the range to the northward. This group of small volcanic vents is situated in latitude 37° 45′ and a little west of longitude 119°, as shown on the accompanying map (Pl. XVII). The following topographic sketch of this cluster of lapilli craters was made by Mr. Johnson, to whom I am also indebted for all the facts relating to the region here presented.

FIG. 12.—A group of recent volcanic cones south of the Mono Craters.

The bluffs to the west of the small craters are of granite, probably a portion of the upheaved side of a fault. The small hills inclosing them on the east are basaltic craters of more recent date than the bowls of lapilli, as is indicated by the topography. With one exception the lapilli craters are symmetric bowls of débris without overflows of lava. The crater forming the exception is of the same type as some of the Mono Craters illustrated by the sections in Fig. 11 and has crags of scoriaceous obsidian rising in its bottom.

Black Point, on the western shore of Lake Mono, is a pre-Quaternary lapilli crater, formed of dark, basaltic lava, of which little more than a ruin remains. Its formation antedates the rise of Lake Mono, and it has been modified by the action of waves and currents until the general form of the ancient volcano is all that can now be distin-

guished. Terraces have been carved on its sides and the resulting débris has been swept away and built into beaches and embankments. During the highest stage of the lake it was deeply submerged. At the present time the waves and currents are carving away its southern base and have formed a bold sea-cliff, which is a conspicuous feature from many points of view. The débris resulting from this excavation is being carried northward by the shore currents, and is finally deposited in a series of bars and embankments now in process of formation along the lake margin.

The difference in appearance between a lapilli crater which has been subjected to the action of waves and currents and one of similar nature that has never been touched by lake waters is shown by Black Point and by Panum Crater on the opposite side of the lake. The former is indefinite in outline and bears the scars left by the attack of the waves; the latter is a perfect bowl, with an unbroken rim and clean sweeping slopes.

INTERSTRATIFIED LAPILLI.

The presence of layers of fine lapilli interstratified with lacustral marl about the shores of Lake Mono, indicates that the Mono Craters were in eruption during the time that the basin was occupied by a much larger water-body than at present. The interbedded layers of volcanic origin are composed of fragments of the same nature as the lapilli of the Mono Craters, and, moreover, increase in size and quantity as one approaches the centers from which they must have originated. The presence of lapilli in thin layers among the Quaternary lacustral deposits at points 10 miles distant from the volcanoes shows that it must have been ejected with great violence and have fallen into the lake as a shower of "ashes."

At the present time the shore of Lake Mono is largely composed of pumice and obsidian, in the condition of sand and pebbles, but this is confined to a narrow band about the lake margin and is not distributed over the lake bottom. It owes its distribution to the transporting powers of waves and currents. In places it is being consolidated into a brecciated sandstone by calcium carbonate derived from the waters of the lake.

In previous reports it has been shown that fine, white deposits of pumiceous dust are common in the sediments of the great Quaternary lake which occupied many of the valleys of northwestern Nevada.[1] The fact was also recorded that identical deposits may be seen among the mountains to the southward of the basin of Lake Lahontan, and at elevations far above the surface of the ancient lake. These deposits correspond both physically and chemically with

[1] Sketch of the Geological History of Lake Lahontan; Third Ann. Rept. U. S. Geol. Survey, 1881-'82 (1883); Geological History of Lake Lahontan, Mon. U. S. Geol. Survey, No. 11, 1885.

the finest of the material known to have been erupted from the Mono Craters. As these volcanoes were the only ones in the region, so far as is known, that erupted acidic lavas in Quaternary and post-Quaternary times, it is concluded that the dust found so abundantly in the Lahontan basin must have been derived from them. The greatest distance from the supposed place of eruption at which the dust has been observed is about two hundred miles. This fact indicates the extreme violence with which the lapilli were ejected.

Deposits of volcanic dust similar to those occurring about Lake Mono have been observed by the writer at several points in Nevada and Utah, but the most of these are certainly of older date than the Quaternary. Among other localities we may mention as of special interest, beds of volcanic dust at least twenty or thirty feet in thickness at the narrows of the Jordan, about twelve miles south of Salt Lake City, and another deposit fully as thick on the steep mountain side, about two miles north of the same city. Other deposits of great extent occur in the mountain ranges in the northern part of the Lahontan basin, and again near Summer Lake, in southern Oregon. Similar deposits are reported from other localities in the Far West by Newberry and King. East of the Rocky Mountains, extensive deposits of volcanic dust have been recognized in Montana, Nebraska, Dakota, and Kansas. These combined observations show that the dust blown into the air during the eruptions of volcanoes extruding acidic lavas has played a somewhat important part in the formation of the Quaternary, Tertiary, and Cretaceous lacustral beds of the western half of our continent. The various centers from which this dust was expelled have not been definitely determined except in the case of the Mono Craters described above.

ASSOCIATED PHENOMENA.

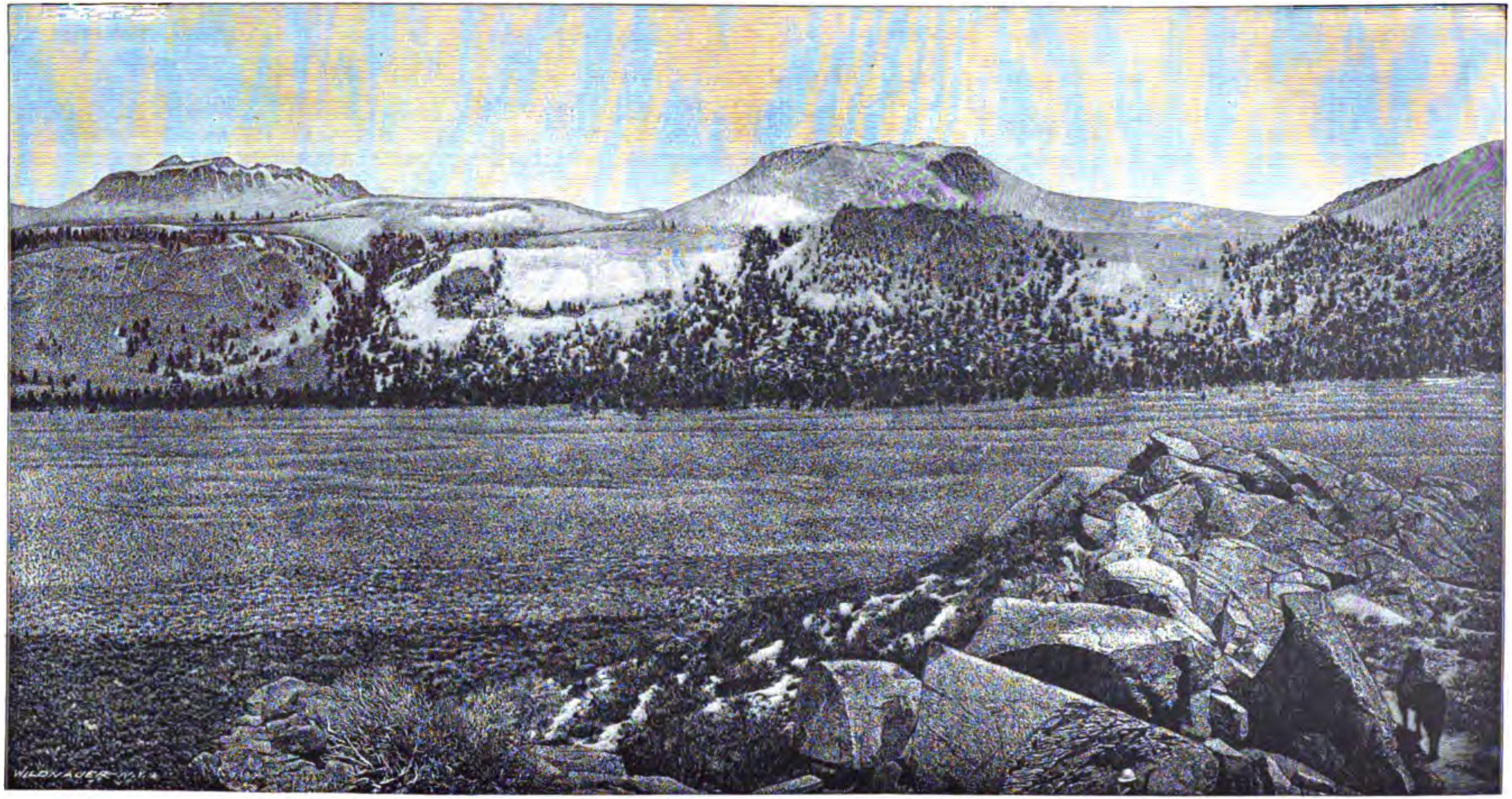
Other craters of quite recent date occur just without the boundary of the hydrographic basin of Lake Mono, but these have not been specially examined by the writer. So far as known, however, they are all basaltic except the little group represented in Fig. 12. Perhaps, on microscopic examination, the rock of which they are composed will be found to be intermediate between andesite and basalt, as is the case with the lavas on Paoha Island; but, whatever their precise petrographic position may be, their basic character renders them distinguishable from the acidic rocks forming the Mono Craters. They are all dark, heavy rocks, and differ in the topographic forms they present as well as in geologic character from eruptions of rhyolite. The large crater just north of Aurora is an example of this class, as are also the smaller ones a few miles to east, the lava flows from which have completely blocked the valley which in pre-Quaternary times afforded drainage either to or from Mono basin.

The small craters south of the Mono basin have already been noticed. Many of these, situated just without our field of study, are so fresh and appear so modern in every way that they certainly seem to be of Quaternary date or younger; but, owing to their isolated position, their age can not be definitely ascertained. They are interesting features in the landscape, and to the lithologist they may perhaps suggest important problems for study, but in the more general geology of the region they are of minor importance.

In the view of the Mono Craters presented on Pl. XXXIX there are two small buttes to the right in the middle distance, which are entirely detached from the craters and are of older date. These same hills appear also in the foreground of Pl. XLIV. They are composed of pink rhyolite, in which angular fragments of the same rock as well as kernels and grains of foreign matter, are inclosed. Fine examples of wind erosion may here be observed, and for convenience of description we may name them the Æolian Buttes. They are fragments of the older history of the region, and, together with many other outliers of granite, andesite, basalt, and rhyolite, indicate that the deciphering of the structural geology of the Mono basin would be a most complicated and difficult task. It could not be accomplished satisfactorily without embracing an extended field along the eastern border of the Sierra Nevada.

One frequently finds among the Mono Craters pebbles and blocks of granite, quartzite, and other durable rocks which are rounded and water-worn, and are entirely foreign to the volcanic products with which they are associated. These are evidently extruded fragments that were brought to the surface during the building of the craters and must have been derived from gravel beds through which the volcanic vents were opened. The fragments are of the same character as the rock found at various points in the Sierra Nevada and must have been transported from the mountains before the volcanoes were formed. Fragments of this character may be found in abundance in the rim of Panum Crater, and were also collected at the very top of the highest cones in the series, thus indicating, as previously pointed out by Le Conte, that nearly the entire range has been formed since the valley was in part filled with gravel.[1] None of the ejected fragments were found to bear evidence of glaciation, and no reason is known to the writer for considering them as having been deposited by glaciers or icebergs, as has been suggested by previous observers. They are simply stream-worn stones. Similar ejected pebbles occur in the crater rims surrounding the Soda Lakes near Ragtown, Nev. In this instance no one could suppose them to indicate that the Carson desert was formerly occupied by glaciers.

[1] On the extinct volcanoes about Mono Lake and their relation to the glacial drift. Am. Jour. Sci., 3d series, vol. 18, 1879, pp. 35-42. See also an account of the same phenomena by Whitney; Geol. Survey California, Geology, vol. 1, p. 455.



CENTRAL PORTION OF THE MONO CRATERS, FROM THE ÆOLIAN BUTTES.
From a photograph.

Ejected fragments, the parent ledges of which are among the peaks of the Sierra Nevada, occur in the post-Quaternary craters of Paoha Island and are scattered over the lacustral sediments surrounding them. These are considered by Le Conte as having been carried to the island by icebergs. In some instances this may possibly be the true explanation of their presence, but, in part at least, they certainly have a history similar to that of the ejected blocks of the Mono Craters. The water-worn pebbles extruded by the volcanoes of Mono Valley have the same connection with volcanic phenomena as do the fragments of limestone, etc., thrown out by Vesuvius.

POST-QUATERNARY OROGRAPHIC MOVEMENTS.

Evidences of recent orographic movements are abundant throughout the Great Basin, as has been shown by many observers. I shall therefore consider my work completed when I have recorded briefly the phenomena of this character in the region we are studying without undertaking the various discussions suggested by them.

One of the most striking proofs of a recent movement of the great fault which determined the eastern face of the Sierra Nevada is a bold scarp about fifty feet high which crosses the morainal embankments at the mouth of Lundy Cañon. This scarp is plainly visible on the inner side of the embankments and is indicated on their summits by depressions. The creek which flows down the deep trough between the embankments cascades over a steep descent of bowlders and gravel where the line of fracture crosses its bed, thus indicating the recency of the orographic movement. It is evident that the mountains have been raised or the valley lowered about fifty feet within a very recent period. A corresponding dislocation of other morainal embankments in the basin has not been observed, but there is evidence that a similar movement has taken place to the southward of Lake Mono at a distance of a few miles from the base of the Sierra.

On the top of Black Point there are a number of open fissures, evidently the result of recent earthquake shocks. These are frequently from two to ten feet broad and from twenty to thirty feet deep. Some of them are lined with calcareous tufa, and hence are of older date than the last high-water stage of the lake. The breadth of the fissures has been increased in some cases since the withdrawal of the lake waters, as is indicated by the adhesion of the tufa to one side of the fissures. The fact that these fractures are not filled with débris attests the recency of their origin.

Along the southern border of Paoha Island there is a broad terrace about ten feet under water, as has already been described, which is broken by fractures and contorted in a wonderful manner. The irregular clay blocks into which the terrace is broken are bounded by open fissures, and some of them have been raised six or eight feet

above their neighbors. The edges of the blocks are ragged scarps, and the fissures between them have not been filled with sediment. The disturbances which produced these results must have been not only violent, but of a very recent date. I know of no direct evidence to sustain the suggestion, but it seems possible that the Owen's Valley earthquake of 1872 may have been felt here.

The lacustral marls forming a large part of Paoha Island have been bent into gentle anticlinals and synclinals, and somewhat faulted, showing that orographic movement has taken place since they were deposited. The deformation of these beds is especially well displayed in the steep scarps south of Hot Spring Cove, where a vertical section, perhaps one hundred feet high, is exposed. The shifting of Lake Mono to the western side of the valley it occupies on account of recent orographic movement has already been described on pages 301–303.

All these observations are in harmony with the evidence of a similar nature obtained throughout Nevada and Utah, which clearly indicates that the earth's crust over this entire region is far from being in a state of stable equilibrium. The recent movement about Lake Mono, as in the region to the eastward, has resulted in the tilting of orographic blocks, but has not produced more than slight contortions or foldings of the strata composing them. Movements among the great rock masses of the region are no doubt still in progress, and when a sudden slip along a fault line takes place the earth vibrates with the shock, and an earthquake is felt.

RÉSUMÉ.

MONO VALLEY IN QUATERNARY TIMES AS COMPARED WITH ITS PRESENT CONDITION.

In the preceding pages I have given a brief sketch of the condition of Mono Valley as it exists to-day and an account of the later geological changes it has undergone. What is here presented is an imperfect history of the basin, as determined from lacustral, glacial, and volcanic records of comparatively recent date. Many facts are known to the writer concerning the changes which took place in pre-Quaternary times, but these have not been correlated and are so disconnected that they would be of but little general interest.

The Quaternary, as compared with the present, appears to have been a time of greatly expanded water surface, increased glacial action, and more energetic volcanic activity. In making such a statement, however, it is evident that we are comparing the events of a day with a whole volume of history. Could we look into the future with as much accuracy as we are able to review the past, it would be evident that changes are now in progress that in time will

equal the apparent revolutions which occurred during the Quaternary. This, as every one will see, is but a restatement of the uniformitarian belief of geologists.

There is no certainty that the volcanic forces which were active at many different periods during the recent history of Mono Valley are now extinct. Volcanoes are paroxysmal in their action. The present time of quiescence may possibly be followed by eruptions as grand as those that built the Mono Craters. It is not safe to predict geologic events, but the causes which led to the former eruptions seem to be working now in the same way as during the ages that have passed. The volcanoes of the region are situated on lines of fracture which are a part of the great Sierra Nevada displacement. Movements have taken place along these faults within the past few years, and the forces tending to produce sudden displacements of the orographic blocks underlying the region are, we may reasonably suppose, still active. At what time a movement may take place that will open fresh fissures through which molten rock may be extruded it is not possible to predict, but such an event seems not unlikely, and, should it take place, it would be simply another occurrence of an event which has already been many times repeated. The relation of Lake Mono to the Sierra Nevada fault and to the volcanoes of the region are such that a movement of the fault might admit the waters of the lake to heated rocks beneath the surface and thus bring on an eruption similar to that which occurred at Rotomahana, New Zealand, in June, 1886. There is a possibility that such an event may have taken place during the building of the Mono Craters, but proof of it is wanting.

The expansion of lakes and the extension of glaciers during the Quaternary are evidence of climatic oscillation. The changes which produced similar results in other quarters of the globe have been made the subject of a voluminous literature. From the consideration of what has been written in relation to such phenomena in other regions, together with personal observations, the writer concludes that the dominant climatic influence, in response to which the glaciers of the Sierra Nevada advanced and retreated, and the lakes in the inclosed basins on the plain expanded and contracted, was variation of temperature. To be sure, one can not postulate a change in any one part of the great machine comprehended in the word "climate" without altering all associated phenomena; but the controlling influence which is held responsible by the majority of writers for the appearance and disappearance of glaciers is temperature. Without entering into the discussion of the nature of the glacial epoch on the northern hemisphere, we may consider the condition of the Mono basin alone, and form a mental conception of the aspect of the region at that time.

At the height of the geologic winter termed the Glacial Epoch,

the Sierra Nevada was white with snow and all the higher regions were buried beneath a vast névé field. Only the tops of the highest peaks and crests along the summit of the range stood above this accumulation of snow and ice. This névé field was the source of numerous ice-streams which flowed down all the cañons previously eroded in the flanks of the range. These glaciers underwent many fluctuations in size and extent, presumably of the same nature as the changes observed in the glaciers of Switzerland during the past quarter of a century. They advanced when the temperature was lowered for a considerable period, and retreated by reason of melting when the climate ameliorated. There were at least two periods of marked extension and many minor fluctuations. What may be termed an interglacial period is recorded in the sediments of the ancient lake by an accumulation of gravel separating two heavy deposits of lacustral sediments. This is the record of a time when evaporation exceeded supply, and it may reasonably be supposed to indicate a period of aridity. It appears from the study of the moraines that there were many fluctuations in the ice-streams which formed them; but it is not clear from this evidence alone that there was a single distinct and important interglacial period more definitely marked than other periods of similar character.

The fact that Lake Mono did not overflow during the Quaternary is evidence that precipitation in the region was not excessive. We may conclude, also, that the cold was not intense throughout the glacial epoch, for the reason that the secondary ice-streams on the sides of the cañons were distributed in reference to minor features of topography. They were mostly confined to the shady side of precipices and cañon walls. Their relation to the relief of the mountains was about the same as that of the small glaciers of the present day. Had the climate been decidedly arctic it could scarcely be expected that the slight difference in temperature between the north and south sides of cañons would have been sufficient to exert such a marked control over the distribution of the local glaciers.

In the opinion of the writer, the changes which brought about the glacial condition were not sudden or excessive, but were oscillations of moderate intensity whose cumulative effects were felt during long periods of time. A moderate decrease of mean annual temperature may reasonably be credited with changing the drainage of the Sierra Nevada from a liquid to a solid form, thus giving origin to the glaciers with the records of which we have become familiar. During the time the glaciers existed on the mountains the winters must have been longer and colder and the summers shorter and less warm than at present.

When the cold wave of the Quaternary had passed its climax and begun to decline, the snow and ice were melted from the mountains and increased the flood of the lowlands. This change was similar to

that which now takes place each year in the same region with the advance of summer. The maximum expansion of the lakes in the inclosed basins at the eastern base of the mountains followed the maximum extension of the glaciers.

There is no decisive evidence in the Mono basin to show that a period of high mean temperature succeeded the glacial epoch. Such an event has been recorded in the Lahontan basin, as described in a previous paper,[1] and may be assumed to have been felt in the neighboring basins as well. Lake Mono has not overflowed since the beginning of the Quaternary, and might reasonably be expected to be a dense saline or alkaline solution. The percentage of saline matter in solution, however, is far below the point of saturation. We have no data for computing the length of time required for the present springs and streams to supply the amount of saline matter now observed in the lake waters. A discussion of this question is much less simple than a similar investigation of the lakes of the Lahontan basin, which, as has been shown, could not have existed under the present conditions for more than two hundred and fifty or three hundred years without being more saline than they are at present. The post-Quaternary history of the Lahontan basin certainly suggests that Mono Valley may also have been completely desiccated at no very distant period.

RELATION OF ANCIENT LAKE MONO TO LAKES BONNEVILLE AND LAHONTAN.

The hydrographic basin that supplied the ancient lake of Mono Valley was adjacent to the much larger drainage area in which Lake Lahontan was situated. Both of these lakes are known to have been in existence at about the same time. As the flooding of contiguous valleys is the result of climatic change, it is evident that the lakes in question must have been contemporaneous. The same reasoning holds good for the other Quaternary lakes in the now arid region between the Sierra Nevada and the Wasatch Mountains. More than a score of independent water bodies of considerable size existed in this region in very recent times, and it is evident that the Quaternary history of the Great Basin can be written only when the facts recorded in these several minor basins shall have been collected and correlated. Only a portion of this instructive region has been geologically surveyed, but enough has been observed to have an important bearing on the general consideration of Quaternary climate and on the character of the change which brought about the glacial epoch.

The nature of the evidence obtained from the study of Lakes Bonneville and Lahontan and the ancient lake of Mono Valley is such

[1] Geological History of Lake Lahontan. Mon. U. S. Geol. Survey, No. 11.

as to justify the conclusion not only that these lakes were contemporaneous, but that they fluctuated synchronously. The two high-water stages of Mono Valley must have coincided with the two well-known flood stages of Bonneville and Lahontan. The interlacustral time of low water was marked in the larger basins by a period of desiccation exceeding the present climate of the region in aridity. So far as the bearing of these several lake histories on the question of climatic oscillation is concerned, there is little that is contradictory in the evidence. All the facts obtained from the study of the later extinct lakes of the northern half of the Great Basin are in harmony with the conclusion that the early Quaternary was a long-continued period of aridity, followed by a time of relatively great humidity, during which a large number of the inclosed basins of the region became flooded. Then followed an interlacustral period of low water, when many, if not all, of the basins were completely desiccated. The second maximum of lake extension followed this arid period and was succeeded by another era of desiccation of great intensity, during which the lakes of the Lahontan basin were evaporated to dryness. A gradual change to a more humid climate brought about the conditions now characteristic of the arid regions of the West.

If the imperfect data now at hand may be trusted, it seems as if the last geologic change of climate had not yet culminated, and that increased humidity in the Great Basin might be expected in the future.

GEOLOGY

OF THE

LASSEN PEAK DISTRICT.

BY

J. S. DILLER.

CONTENTS.

ILLUSTRATIONS.

GEOLOGY OF THE LASSEN PEAK DISTRICT.

By J. S. Diller.

INTRODUCTION.

The geological survey of the Cascade Range, under the direction of Capt. C. E. Dutton, was commenced in 1883. At that time the writer was sent out to make a general reconnaissance of the range in the northern part of California and Oregon. A party outfitted at Red Bluff, and after ascending Lassen Peak and Mt. Shasta proceeded northward through Oregon along the eastern base of the range. From this line of travel detours were made to examine the summit of the range at Crater Lake, Mt. Scott, Union Peak, Mt. Thielson, Diamond Peak, and the Three Sisters. Crossing the range at Mt. Hood, the party returned along its western base to California. Since then three field seasons have been devoted to the study of volcanic phenomena in the vicinity of Mt. Shasta and Lassen Peak.

The preliminary survey of the Cascade Range clearly indicated that the point at which to begin a study of its details was in the vicinity of Lassen Peak. This locality was considered of particular interest on account of the great variety of its lavas, the recency of some of its volcanic eruptions, and the vigorous solfataric action which still survives. It was anticipated also that a careful study of this region would solve one of the perplexing geographic problems of the Pacific coast, viz., the relations between the Coast, Cascade, and Sierra Nevada Ranges.

The district has been found replete with a great variety of interesting phenomena, only part of which can be discussed at present. This initial report will be restricted to a consideration of the geologic history of the region as chronicled in its stratified deposits. Special reference will be made to the development of the Sierra Nevada Range and the relation of its great structural features to the volcanic phenomena in the vicinity of Lassen Peak, leaving the particular discussion of the latter for another occasion.

HYPSOGRAPHY.

GENERAL HYPSOGRAPHIC FEATURES.

The belt of country lying between the Great Basin and the Pacific may be regarded as grouped naturally into two valleys and three mountain ranges. The Coast Range is separated from the Cascade

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upon the north by the valley of the Willamette, and upon the south from the Sierra Nevada by the broad depression drained by the Sacramento. Near the State line between Oregon and California the three ranges meet in common ground, among a group of ridges and peaks so complex as apparently to render the definition of the ranges a matter of considerable difficulty. It is true, nevertheless, that each range is sharply characterized by its geologic development, and everywhere within this mountain plexus its limits are clearly defined.

HYPSOGRAPHY OF THE LASSEN PEAK DISTRICT.

The position and boundaries of the Lassen Peak district are represented in Fig. 13. Its primary hypsographic features are the volcanic

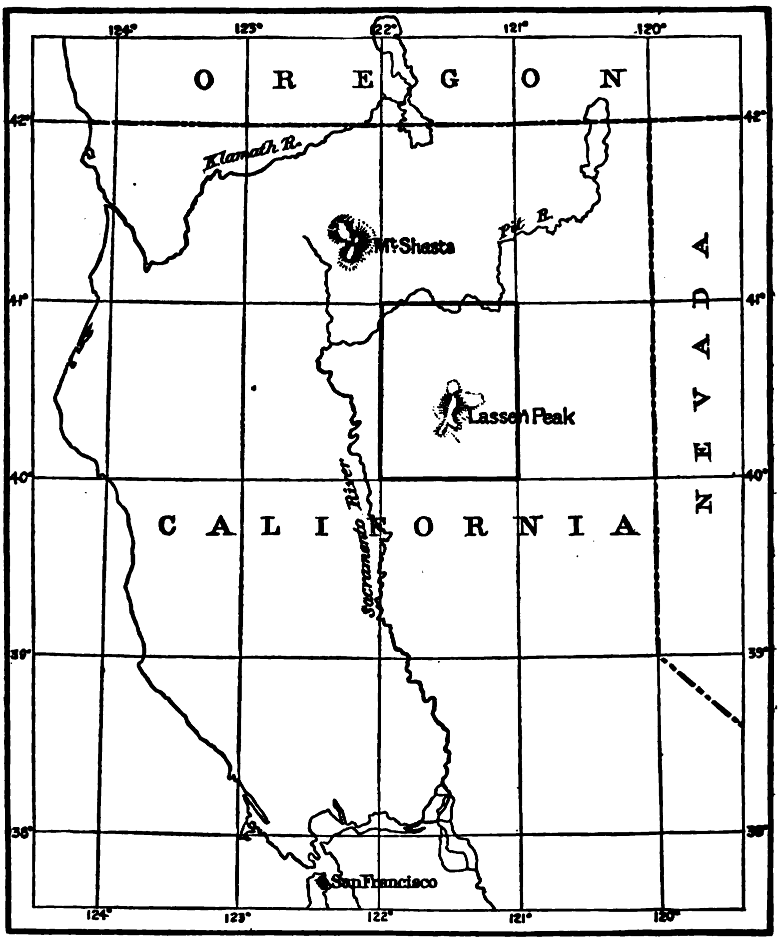
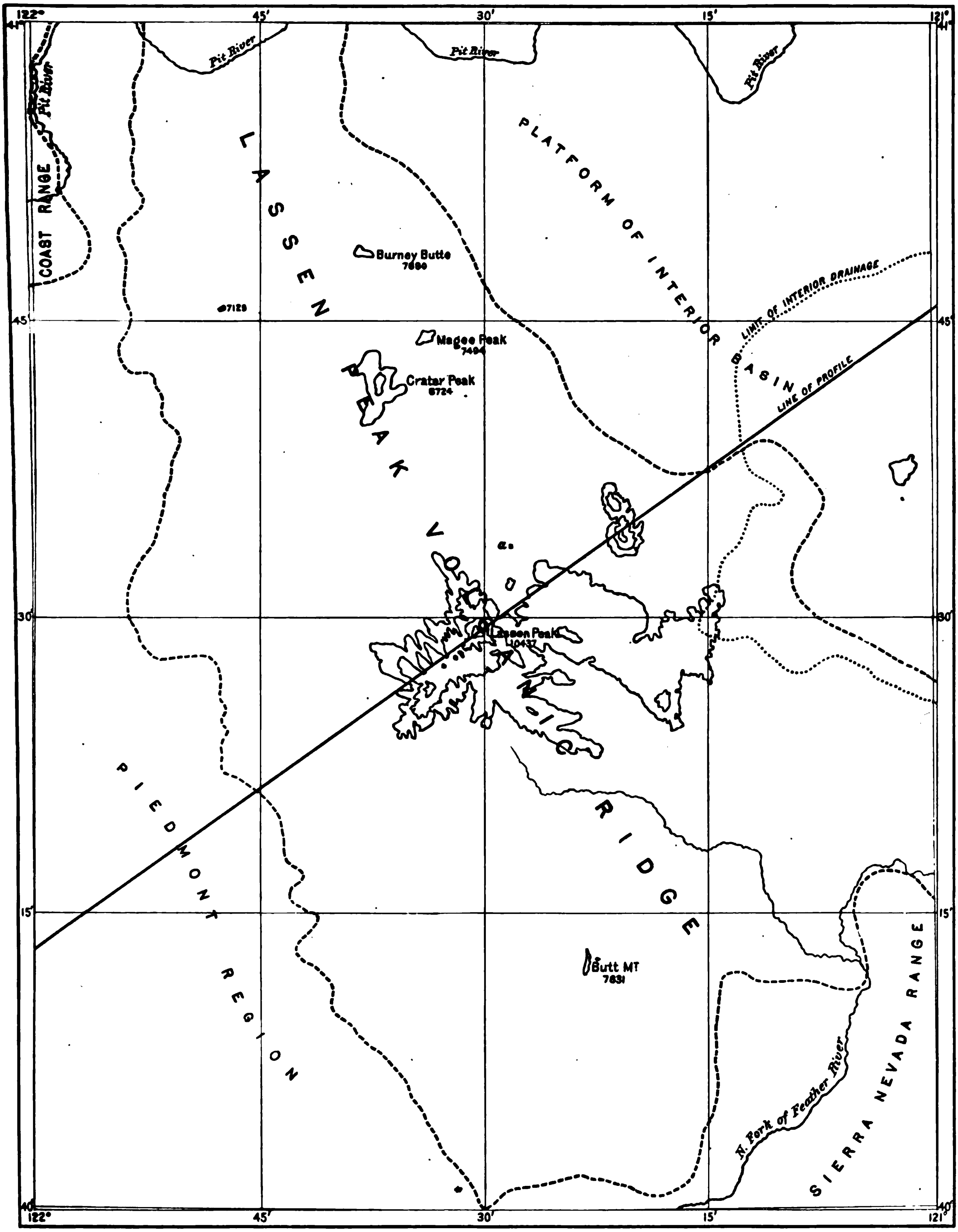


FIG. 13. Position and boundaries of the Lassen Peak district.

ridge, the Piedmont, and the Great Basin platform, all of which are outlined on the accompanying illustration (Pl. XLV). Lassen Peak stands in the midst of a belt of volcanic cones stretching from the



HYPSOGRAPHIC DIVISIONS OF LASSEN PEAK DISTRICT.

north fork of Feather River to Pit River. The coalescent lavas from a multitude of vents join the bases of the cones in such a way as to form an irregular serrated ridge entirely unlike those of the Sierra Nevada range in form, composition, structure, and origin. The view in Pl. XLVI may be seen from an elevation of 6,000 feet near Hat Creek, north of Lassen Peak, looking northwest parallel with the ridge. The whole width of the ridge is here shown from the Great Basin platform on the right across Crater Mountain, whose long gentle westward slopes reach the Sacramento Valley. To the northward the ridge becomes less prominent and narrowed by the impingement of the Great Basin platform, which is dotted over with small cones having no serial arrangement. Although it rests directly upon stratified rocks, the ridge, throughout a length of nearly seventy-five miles and a breadth of over twenty miles, is composed chiefly of accumulated lava and volcanic débris. By far the most majestic of this group of ancient volcanic piles is Lassen Peak, which, with its many prominent spurs, rises to an elevation of 10,437 feet, and bears large patches of perennial snow. The other prominent peaks of the belt, which attain an elevation of over seven thousand feet, are represented above that level in thousand-foot contours.

The Piedmont region, lying at the western foot of the volcanic ridge, is most prominently developed in the southern portion of the district, where it is a broad, even platform of stratified deposits gently inclined westward to the Sacramento Valley, from which it is sharply separated, as represented in Fig. 14, by a prominent bluff. All of the mountain streams on their way to the Sacramento cut deep cañons across the Piedmont.

The volcanic ridge of Lassen Peak appears to be a continuation of the Sierras, but in reality, as we shall see in the sequel, it is the connecting link between the Sierras and the Coast Range, and itself belongs geologically to the Cascade Range.

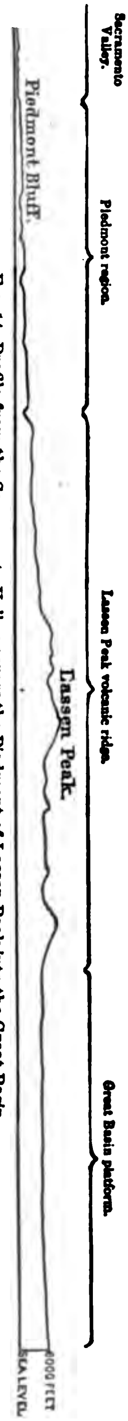


Fig. 14. Profile from the Sacramento Valley across the Piedmont of Lassen Peak into the Great Basin.

GEOLOGY.

GEOLOGIC FORMATIONS IN THE LASSEN PEAK DISTRICT.

The portions of the country immediately observed by the writer while preparing the geologic map are indicated in Pl. XLVII by the routes of travel. About a thousand specimens of rocks were collected and most of

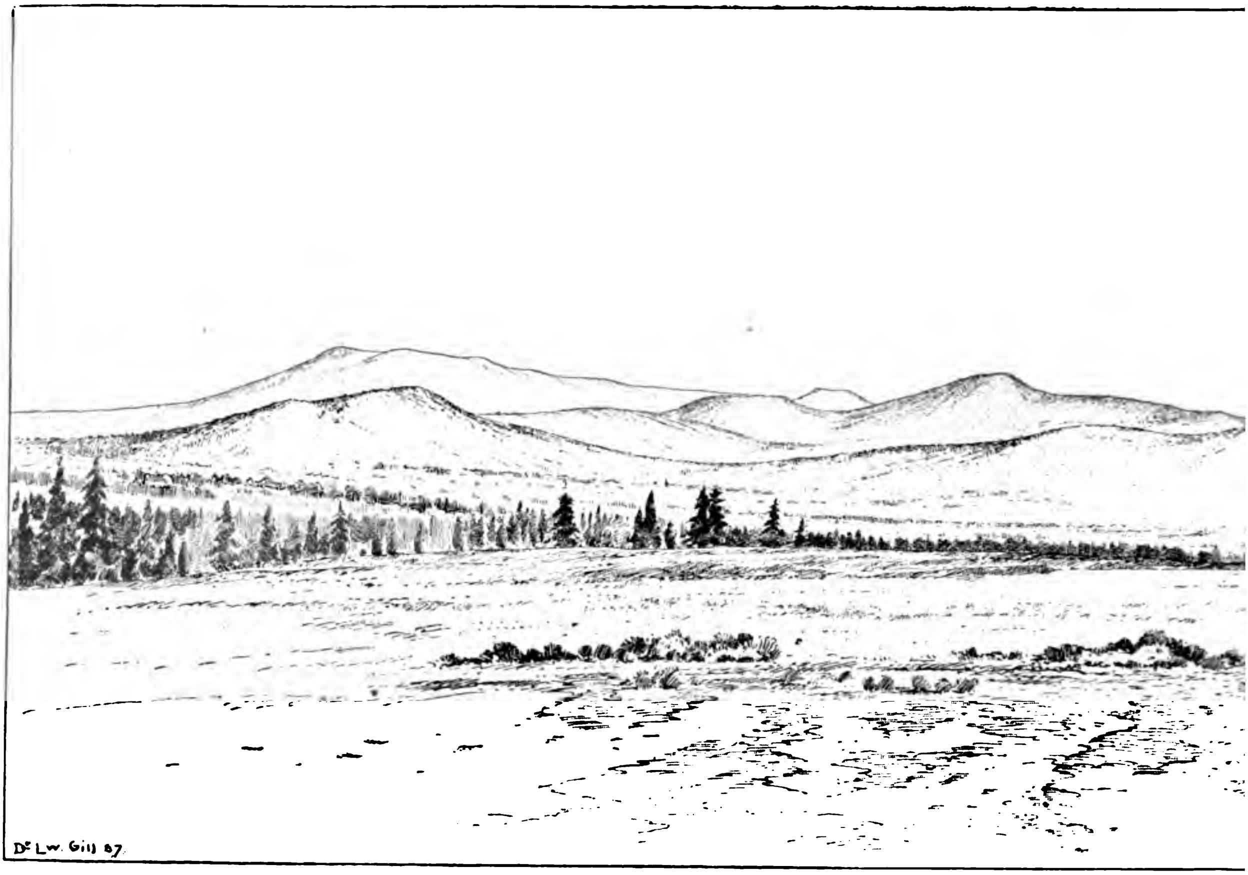
them were examined microscopically. Ten formations, including stratified deposits of at least five geologic horizons and as many kinds of eruptive rocks, have been recognized in the region and delineated upon the geologic map (Pl. XLVII). Within the auriferous slate series of the district the only geologic horizon which has been determined by fossils is the Carboniferous limestone. Only the lower member (Chico beds) of the Chico-Tejon series was recognized within the district. The Tertiary consists chiefly of Miocene, but very probably embraces also the Pliocene. The eruptive rocks are rhyolite, quartz-andesite (dacite), hornblende andesite, hypersthene andesite, basalt, and quartz basalt; they will be described in another report. The sedimentary rocks will be considered in the order of age, beginning with the oldest, the auriferous slates.

AURIFEROUS SLATE SERIES.

The auriferous slate series is a very heterogeneous group of comparatively ancient sedimentary and eruptive rocks, most of which have been subjected to extensive modification, both in structure and position, since they were formed.

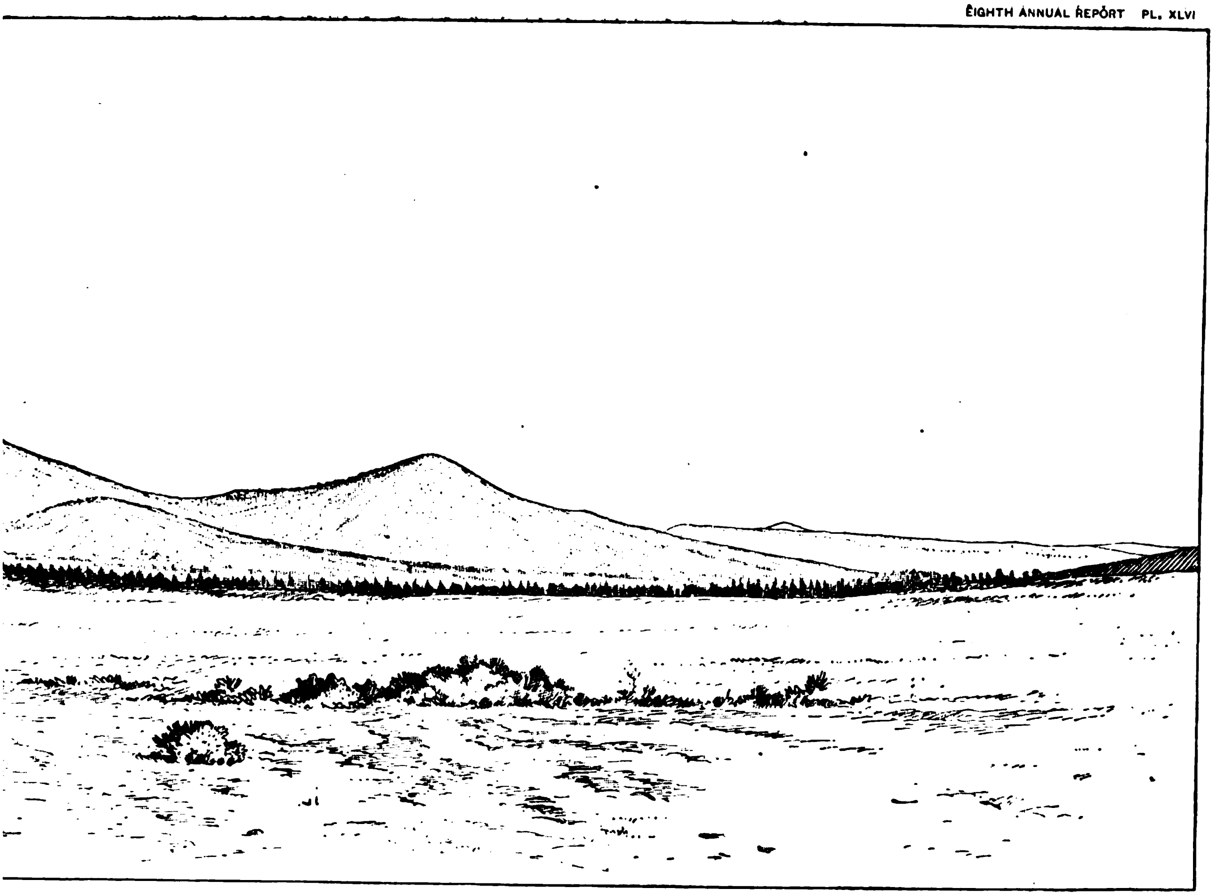
Distribution.—They occupy two areas at opposite extremities of the Lassen Peak district, one in the vicinity of the North Fork of Feather River and the other near Pit River. The former is at the northern terminus of the Sierra Nevada Range, where this series of gold-bearing rocks is extensively developed, and the latter is at the end of the eastern extension of the Coast Range. These rocks do not cover as large an area in the Coast Range as in the Sierras; nevertheless they form a large portion of northwestern California and the adjacent portion of Oregon. All of the other rocks of the district are younger than the auriferous series, and there is every reason to believe that if all of these newer rocks were swept away from the region between the North Fork of Feather River and Pit River, it would be found that they occupy a large depression in the auriferous series. This depression, transverse to the general trend of the Sierras, is a very important feature in the geographic and geologic development of that country, and I shall have frequent occasion to refer to it as forming the boundary between the Sierras and the Coast Range. From the latter portion of the Cretaceous into the Pliocene, inclusive, the depression was occupied by water, to which, for convenience, the name Lassen Strait will be applied.

Carboniferous limestone.—Among the auriferous series those formed of fine detrital matter appear to prevail, and their slaty character early suggested the name "auriferous slates" for the whole series. Interstratified with these are numerous lenticular masses of limestone containing fossils of Carboniferous age. Occasionally it is so metamorphosed as to obliterate all traces of organic remains; nevertheless their geographic distribution and relation to masses



TRANSVERSE PROFILE OF LASSEN PEAK

Seen from Hat Creek, at an elevat



IC RIDGE ACROSS CRATER MOUNT.
00 feet, looking northwest.

containing fossils are such as to indicate that all are essentially of the same age.[1]

The metamorphism of the series is general, but at different points it varies greatly in intensity. In some of the finer deposits the original sedimentary character is very well preserved, but in others it is entirely obliterated by the subsequent development of a completely crystalline structure. Although finer sediments appear to predominate, those of coarser texture are by no means wholly wanting, and some of them, as we shall see presently, contain interesting fragments of older terranes.

Serpentine.—Mingled with the metamorphosed sedimentary rocks are numerous irregular masses of eruptive origin. They are chiefly of a basic character. Coarse granular plutonic rocks, such as diorites, gabbros, and peridotites, appear to be most abundant; but regular volcanic effusions are found also, together with strata composed of lapilli and volcanic sand usually in a highly altered condition.

Perhaps the most interesting rocks of the auriferous series within the Lassen Peak district are the serpentines. They appear to have a very different origin from those of the Coast Range described by Mr. G. F. Becker.[2] The serpentine which forms the prominent "Red Hill" in the junction of Indian Creek (eastern branch) and the North Fork of Feather River may be taken as a typical example of these rocks, and its genesis is exactly analogous to that of many other masses of serpentine in the northern portion of the Sierras and Coast Range. Serpentine forms a large portion of Red Hill and frequently exhibits an interesting fissile structure, splitting up into more or less distinctly lenticular, platy fragments with slickensides, as if the serpentine had been subjected to great stress, producing motion within the mass. Intimately intermingled with the well developed serpentine are both large and small irregular compact masses of olivine, which are completely permeated by a fine network of serpentine resulting from its alteration. The reticulated structure of the serpentine and its intimate association with olivine throughout the whole mass demonstrate beyond question that all the serpentine is derived from the alteration of olivine, and it is possible that the increase of volume attending the change may have given rise to the stress necessary to produce the fragments with slickensides. The rock was originally a dunite, for it was composed almost wholly of olivine

[1] Within the Lassen Peak district the limestone is exposed in nearly half a dozen places. Upon the divide east of Yellow Creek, south of Humbug Valley, it contains numerous characteristic fossils, but at the exposures in the hills between Butte Valley and Prattville, and at various points along the cañon of the North Fork of Feather River, no fossils have been observed. To the northwestward, just outside of the district mapped, there are a number of exposures of the same limestone with an abundance of Carboniferous fossils. (See Bull. U. S. Geol. Survey, No. 33, 1886, pp. 10–12.)

[2] Am. Jour. Sci., 3d series, 1886, vol. 31, p. 348.

with small amounts of ilmenite and a few other accessory minerals. The dunite altered chiefly to serpentine, but frequently also to needle-shaped crystals and fibrous bunches of tremolite.[1] In the latter case the weathered surface of the rock is usually colored yellowish-red by oxide of iron, and this suggested the name of the hill. Between Quincy and Spanish Ranch, as well as near Round Valley reservoir,[2] west of Greenville, in Plumas County, and at Mt. Eddy, west of Berryvale, in Siskiyou County, are great masses of serpentine containing large remnants of olivine in such a way as to clearly indicate that the original rock was a peridotite.[3]

Age of the auriferous slate series.—It is well known, from the investigations of Whitney, Becker, White, and others, that the auriferous series contains both Mesozoic and Paleozoic strata, and that a large part of it belongs to the latter system. Marcou has long contended that a large portion of the strata of the Sierra Nevada Range is older than the Mesozoic, and the evidence favorable to such a view appears to be cumulative. The writer was first led to regard a very considerable portion of the series as lying below the Carboniferous limestone by an examination of the section at the head of Soda Creek, south of Mt. Shasta. There it is evident that the large mass of black shale which has a wide distribution in that vicinity lies below the Carboniferous limestone in which fossils have been found. This view was strengthened by observations at numerous other points, among which may be mentioned Hough's Mountain, between Indian Valley and American Valley, where the apparently older portion of the series is exposed by a great fault.[4] Upon the western slope of the mountain, however, the varied position of the strata renders this section less satisfactory.

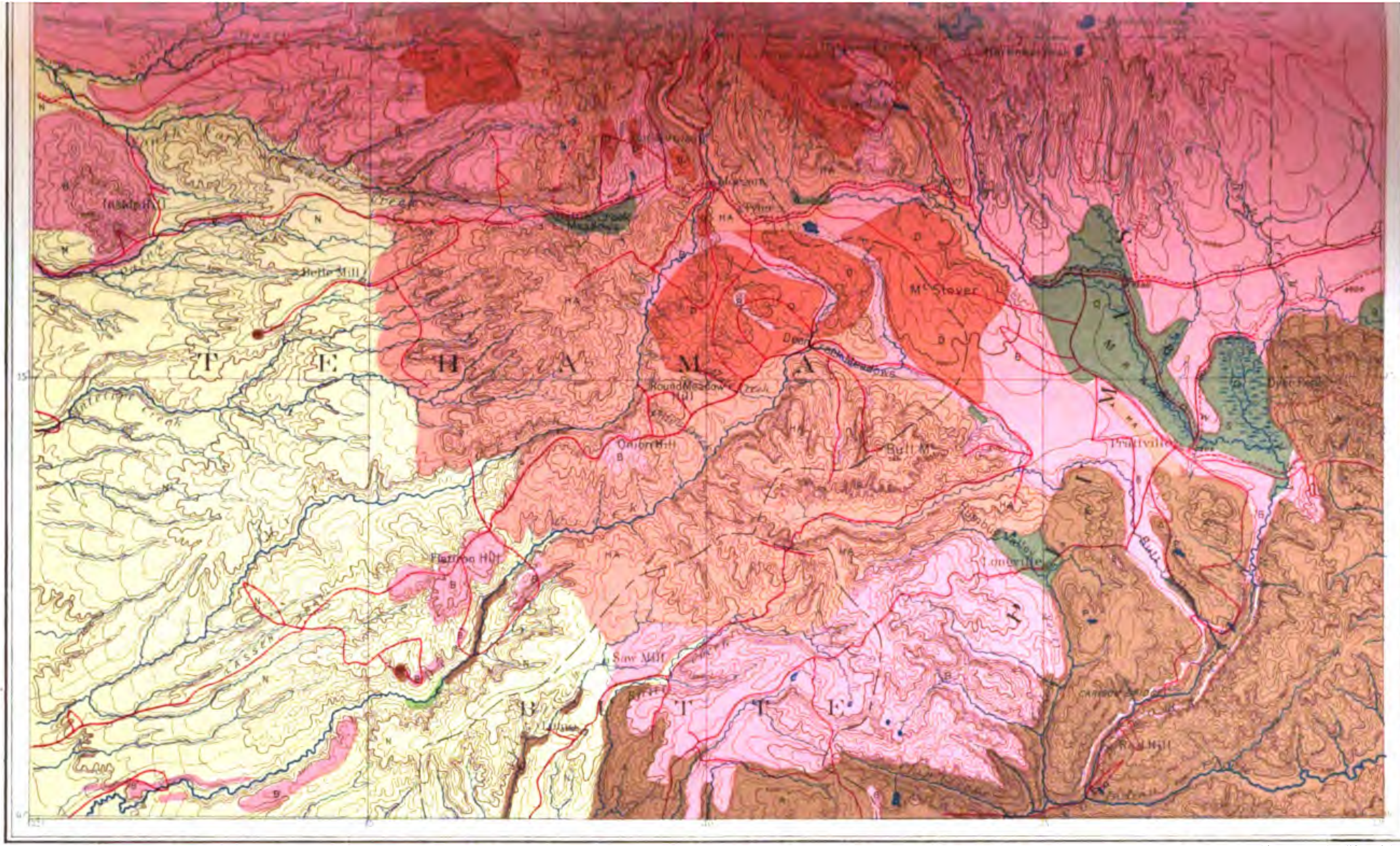
A better exposure occurs in Shasta County, along Little Cow Creek, just below the point where it is crossed by the Oak Run road. The Carboniferous limestone, with traces of fossils, is distinctly underlaid by a conglomerate and black shale, both of which are evidently older than the limestone; for, as the conglomerate overlies the shale and contains its fragments, it is evident that there has been no overturning or the conglomerate would contain fragments of the limestone instead of the shale. The conglomerate contains much pyrite, and is considerably altered. Some of its pebbles are so metamorphosed as to indicate that they were derived from an older metamorphic rock, and demonstrate that below the Carboniferous limestone there is a considerable series of older stratified rocks whose age is unknown. As it becomes more and more evident that a large

[1] Bull. U. S. Geol. Survey, No. 38, 1887, p. 24.

[2] At this locality a large number of specimens of serpentine were collected for the educational series of rocks.

[3] Dr. M. E. Wadsworth, in his Lithological Studies, p. 158, describes three serpentines from the Sierras and regards them as altered peridotites.

[4] Bull. U. S. Geol. Survey, No. 33, 1886, pp. 13, 14.



SEDIMENTARY ROCKS

QUATERNARY Recent Lake Deposits

NEOCENE Pliocene & Miocene — N

CRETACEOUS Chico — C

CARBONIFEROUS (Limestone)

Auriferous Slates

ERUPTIVE ROCKS

Quartz Basalt

Basalt — B

Rhyolite and Quartz Andesite (Dacite) — D

Hypersthene Andesite — HA

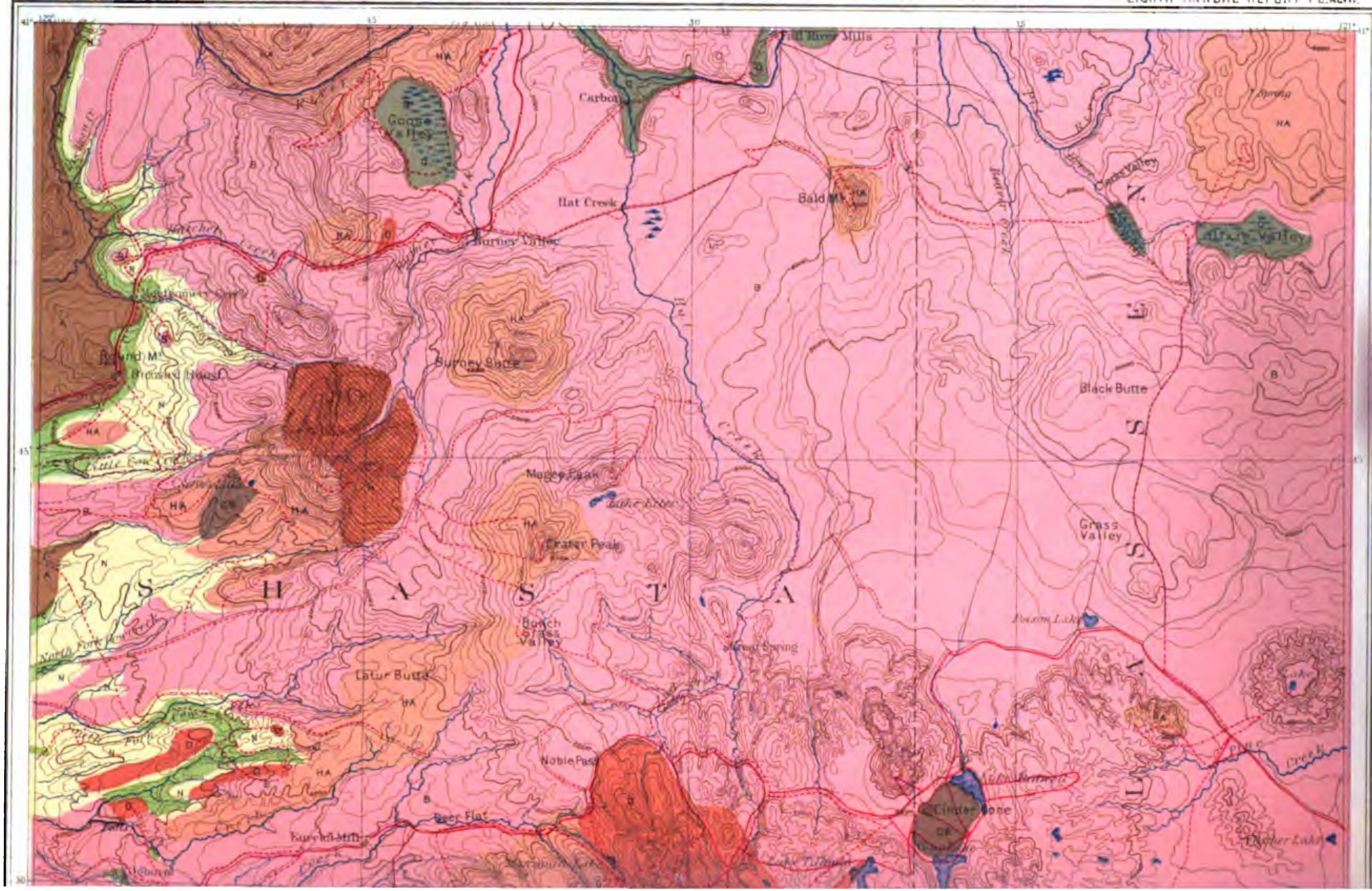
Hornblende Andesite

Routes of travel 1885 ———— 1886. - - - - - -

GEOLOGIC MAP OF LASSEN PEAK DISTRICT.

BY J. S. DILLER.

Scale 1: 100,000.


Goose Valley
Carbon
Fall River Mills
Hat Creek
Burney Valley
Bald Mt.
Burney Butte
Round Mt.
Buzzard Roost
Magee Peak
Lake Eiler
Crater Peak
Black Butte
Grass Valley
Poison Lake
S H A S T A
L A S S E N
Bunch Grass Valley
Latur Butte
Noble Pass
Beer Flat
Cinder Cone
Butte Lake
Snag Lake
North Fork Cow Creek
Little Cow Creek
Hatchet Creek
Burney Creek
Clarks Valley
Dixie Valley
HA
B
N
CB

part of the auriferous slates is Mesozoic, so also the evidence is accumulating in favor of the view that another large portion is older than the limestone and possibly pre-Carboniferous.

CRETACEOUS—CHICO BEDS.

Composition.—The Chico-Tejon series is composed chiefly of soft, yellowish olive sandstone, but frequently also considerable masses of conglomerates and shales occur. The sediments of which they are composed were evidently derived directly from the auriferous slates upon which they repose unconformably. Fragments of volcanic rocks are indeed not uncommon among the pebbles of the Chico conglomerates, but they are usually much altered and quite unlike the modern lavas of the Lassen Peak district.

Distribution.—The Chico-Tejon series has a wide distribution throughout the great central valley of California, and outcrops at many places along the foothills upon both sides. The lower member of the formation reaches the very northern limit of the valley and extends eastward through the Lassen Peak district, beneath modern lavas, far into Oregon. Formerly it was completely covered by later stratified deposits, but at a number of places in the Piedmont region these have been removed and the strata of the Chico group again brought to light.

In the cañon of Chico Creek, between eleven and sixteen miles east of the village of Chico, the yellowish olive Cretaceous sandstone is well exposed for several hundred feet. It has yielded at this locality a few fossils, which were identified by Dr. C. A. White. They are noted in the list of fossils, p. 410.[1] These fossiliferous sandstones dip westerly about 6 degrees, while the inclination of the overlying stratified tufas is considerably less. As the declivity of the stream is not so great as that of the Cretaceous sandstone, they disappear beneath its bed before reaching the limit of the Piedmont region. At its eastern border the Cretaceous sandstone attains an elevation of about one thousand eight hundred feet above sea level, and rests unconformably upon the contorted auriferous slates.

Similar strata have been observed in the cañons of Deer and Mill Creeks, but no fossils were seen by the writer at either of these localities. Fossils have been reported, however, in these cañons, and also in that of Antelope Creek, by the late Professor Gans, of Red Bluff, but their exposures could not be found within the time at my disposal. At the Tuscan Springs, six miles east of Red Bluff, and just outside of the western border of the map, there is an exposure of the Cretaceous rocks which has yielded Professor Whitney an abundance of fossils.[2]

Proceeding northward, the next locality for Cretaceous fossils is in the dry bed of a small stream near the eastern base of a prominent

[1] Most of these fossils are unlike the ones collected by Professor Whitney at the same locality. (Geol. Survey California, Geology, vol. 1, 1865, p. 209.)

[2] Ibid., p. 207.

cinder cone in Shasta County, about six miles southwest of Shingletown. The exposure is a very small one, laid bare by the removal of the superincumbent tufas. Numerous fossils are said to have been collected at an outcrop south of Darr's saw mill and at the falls in the South Fork of Bear Creek, but the limits of the exposure have not been traced.

Upon the North Fork of Bear Creek and the South Fork of Cow Creek is a large tract of Cretaceous characterized by its organic remains. These two streams are separated by a prominent ridge which is perhaps generally known in that vicinity as Bear Creek Hill. It is capped by a remarkably interesting flow of streaked lava lying upon volcanic and other sediments, which in turn are underlaid by the Cretaceous. Near the northern base of this ridge the fossiliferous sandstone dips at an unusually high angle (12°) southeasterly beneath the hill in such a way as to suggest that the hill originated in part by dislocation. At an elevation of 1,600 feet, near the western end of this ridge, in a gulch opening into the South Fork of Cow Creek, a few fossils were collected.[1] Prominent among them is *Baculites chicoensis*. At Coal Gulch, upon the North Fork of Cow Creek, traces of coal have been found and prospected unsuccessfully in the Chico group. A short distance farther north, on the South Fork of Clover Creek, the fine, shaly beds of the same formation contain a number of fossils.[2] At this point the Cretaceous is found resting directly upon the contorted and highly metamorphosed auriferous slates. In the same neighborhood, one-half a mile south of the falls in the North Fork of Clover Creek, a large number of specimens of an interesting fossil oyster were found. It occurs at an elevation of 1,300 feet and forms a veritable shell heap, filling a small depression in the metamorphic rocks by which it is completely surrounded, although within a few yards of the border of the characteristic fossiliferous Cretaceous sandstone. There can be no doubt that this fossil oyster belongs to the Chico group, and as it is new, a brief description of it by Dr. White is given below.[3]

A few miles beyond the western limit of the map, between the north fork of Cow Creek and Clover Creek, at Basin Hollow, is an interesting and very instructive exposure of the Cretaceous rocks, where over two hundred and fifty feet of them may be examined. They are composed chiefly of fine shales, but there are prominent

[1] Lot number 2 in the list, p. 410.

[2] Lot numbered 4, p. 410.

[3] *Ostrea* (*Alectryonia*) *Dilleri* White.—Shell sub-elliptical in marginal outline, the irregularity of which is increased by a more or less prominent posterior wing; both valves more or less convex, but the lower one more capacious than the other; muscular impression large, and situated in the postero-dorsal region. Surface marked by numerous strong radiating ribs, which give the free margin a strongly dentate character. (See Bull. U. S. Geol. Survey, No. 50, Pls. 1 and 2.)

ledges of sandstone and conglomerate also. One bed of the latter is nearly twenty feet in thickness and contains some pebbles which are at least four inches in diameter. Chico fossils[1] are found abundantly both above and below as well as within the conglomerate. The fine shaly beds during the rainy season give rise to the peculiarly adhesive and never-to-be-forgotten mud which is known throughout the West as adobe. The adobe land upon the northeastern border of the Sacramento Valley is all confined to the outcrop of the rocks of the Chico group, and a knowledge of this fact is of great service in tracing its outlines.

On Little Cow Creek, where it is crossed by the Oak Run road, there is a fine exposure of fifty feet of Chico conglomerate, containing near its base numerous fossils.[2] Its unconformable contact with the auriferous slates is very well exposed. Overlying the conglomerate is a mass of fine sandstones and shales, which, according to Mr. Luppe Eiler, who has thoroughly prospected the country, occasionally contains thin seams of coal. At one locality it is said about five tons of coal were mined before the supply was exhausted, but the quality of the coal did not prove satisfactory. From Little Cow Creek the Chico group forms a belt skirting the auriferous slates northeasterly, then northerly beyond the Pit River. It is a near-shore deposit all the way, abutting directly against and resting unconformably upon the auriferous slates from which it was derived. The latter extend far northwestwardly into the Coast Range. The actual presence of the unaltered Cretaceous rocks along this belt is demonstrated by a number of fossils, including the genera *Ammonites* and *Inoceramus* found at Kosks Creek, in the great bend of Pit River.

Age of the fossils.—As already stated, a large number of fossils were collected from the series of rocks now under consideration. They were studied by Dr. C. A. White, whose list of identified forms from each locality is given in the following table. Concerning the fossils as a whole, he says that "they all belong to the Chico group, i. e., the lower or Cretaceous member of the Chico-Tejon series. None of the forms suggests the presence of the Horsetown beds below or the Tejon member of the series above."

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[1] Lot No. 3, p. 410. [2] Lot No. 6, p. 410.

List of identified forms.

No. 1. Cañon of Chico Creek, 15 miles east of Chico.

Trigonia Evansana	Meek.
Venus varians	Gabb.
Fulguraria Gabbi	——.
Cinulia obliqua	Gabb.
Turritella uvasana	Con.
Baculites chicoensis	Trask.
Aporrhais falciformis	Gabb.
Ammonites Newberryanus	Meek.
Ammonites chicoensis	Trask.
Gasteropod, sp. nov.	

No. 2. Gulch on south side of South Fork of Cow Creek; elevation 1,600 feet.

Modiola cylindrica	Gabb.(?)
Nucula truncata	Gabb.
Baculites chicoensis	Trask.

No. 3. West end of Basin Hollow, near Blodget's.

Trigonia Evansana	Meek.
Axinæa Veatchi	Gabb.
Venus varians	Gabb.
Axinæa sagittata	Gabb.
Tellina undulifera	Gabb.
Dentalium Cooperi	Gabb.
Cinulia obliqua	Gabb.
Gasteropod, sp. nov.	

No. 4. South Fork of Clover Creek; elevation about 1,400 feet.

Axinæa Veatchi	Gabb.
Tellina Hoffmaniana	Gabb.
Pugnellus hamulus	Gabb.
Fulguraria Gabbi	White.
Cinulia obliqua	Gabb.

No. 5. One-half mile south of Clover Creek Falls.

Ostrea Dilleri	White.

No. 6. Little Cow Creek, one-fourth mile below Oak Run Road Crossing.

Axinæa sagittata	Gabb.
Tellina Hoffmaniana	Gabb.
Tellina undulifera	Gabb.
Tellina Ashburneri	Gabb.
Meretrix nitida	Gabb.
Axinæa Veatchi	Gabb.
Gyrodes Conradiana	Gabb.
Lunatia unciformis	Gabb.
Nucula truncata	Gabb.
Gasteropod, sp. nov.	
Gasteropod, sp. nov., like in No. 3.	

No. 7. Little Cow Creek, 2 miles east of Woodman's, 20 miles east of Redding.

Axinæa Veatchi	Gabb.
Pugnellus manubriatus	Gabb.
Actæonella oviformis	Gabb.
Gyrodes Conradiana	Gabb.

No. 8. Little Cow Creek, near Joseph Yanks, 16 miles east of Redding.

Axinæa Veatchi	Gabb.
Cucullæa Mathewsoni	Gabb.
Ostrea	——.
Trigonia Evansana	Meek.
Actæonina pupoides	Gabb.
Anchura monilifera	Gabb.
Gasteropod, sp. nov.	
Gasteropod, sp. nov.	

Species common to several localities:

	Lots.
Axinæa Veatchi	3,4,6,7,8
Trigonia Evansana	1,3,8
Cinulia obliqua	1,3,4
Axinæa sagittata	3,6
Tellina Hoffmaniana	4,6
Tellina undifera	3,6
Baculites chicoensis	1,2
Venus varians	1,3
Gyrodes Conradiana	6,7

Upper and lower limits.—The Chico rocks are chiefly soft, friable, yellowish-olive sandstones, which continue to occupy almost the same position as that in which they were originally laid down, excepting perhaps the exposures at Tuscan Springs, and at the northern base of Bear Creek Hill. Since their deposition, although they have been subjected to very moderate differential uplifting, they have not experienced the slightest metamorphic changes, and remain entirely unaltered. On the other hand, the auriferous slates upon which they have been found at a number of places to discordantly repose were greatly metamorphosed before the beginning of the Chico epoch. The interval between the time when the auriferous slates assumed their present structure and position and the beginning of the Chico epoch may have been a very long one, but it has no representative among the formations of the Lassen Peak district. The lower limit of the Chico group is clearly defined, but the upper limit in the same district is not easily determined. Messrs. White and Becker[1] have shown that in the southern portion of the great valley of California the Chico-Tejon series is very extensively developed, attaining the enormous thickness of 10,000 feet. Its maximum thickness in the middle of the northern portion of the Sacramento Valley is as yet unknown, but the greatest observed is only a few hundred feet. It must be remembered, however, that the only portion of the series now exposed is its edge, much attenuated upon the borders of the great depression (Sacramento Valley) which it fills. The presence of the lower member of the Chico-Tejon series in the Lassen Peak district is a matter beyond question, and the absence of the upper member can hardly be doubted. This state of affairs brings the Miocene into the place of the Tejon, a condition which was not fully recognized until the fossils were determined. This subject will be adverted to again when considering the Miocene.

GEOGRAPHY OF THE DISTRICT DURING THE CHICO EPOCH.

The geography of northern California during the Chico epoch is outlined upon the accompanying sketch (Fig. 15). Attention has already been called to the fact that the Chico beds at the northeastern extremity of the Sacramento Valley, in the vicinity of Pit River, are near-shore deposits. The shore line can be traced from this point westward and southwestward along that part of the Coast Range which bounds the northern extremity of the Sacramento Valley. To the northward the littoral deposits appear along the western border of Shasta Valley, in the vicinity of Yreka, and may be traced directly into Oregon. It is evident that these shore deposits were derived from an insular area of the auriferous slates

[1] Bull. U. S. Geol. Survey, Nos. 15, 19, 1885.

which now form the prominent mountains of northwestern California and the adjacent portion of Oregon.

Near Pence's ranch, twelve miles north of Oroville, there are interesting exposures of Chico rocks which rest directly and discordantly upon the auriferous slates. They rise in the foothills of the Sierras to an elevation of about one thousand feet above sea level, but do not reach Cherokee flat. At that place strata younger than the Creta-

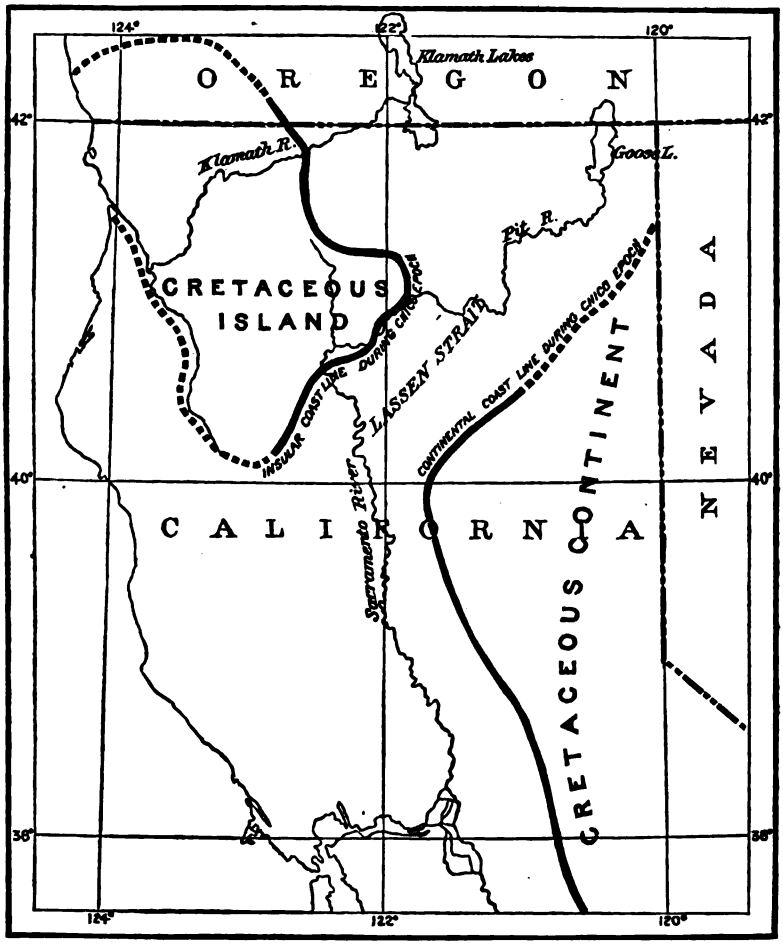

FIG. 15. Geography of Northern California during the Chico epoch.

ceous rocks of the neighborhood repose immediately upon the metamorphics. In the cañon of Chico Creek, where the Chico beds were next examined, they rise upon the western slopes of the auriferous series to an elevation of about eighteen hundred feet, and, as at Pence's, dip slightly to the westward away from the old shore line along the western border of the sierra platform. From this point northerly the littoral deposits are covered up by the extensive effusions of lava.

from the volcanoes in the Lassen Peak district, but there can be no doubt that the ancient coast extended northeasterly around the northern end of what is now the Sierra Nevada range towards the headwaters of Pit River, and that during the Chico epoch the Lassen Peak district lay almost wholly within Lassen Strait, which separated the island of northwestern California from the continental land to which the Sierra country belonged.

MIOCENE.

Composition of the Miocene strata.—The Miocene formation embraces sandstones with finer sediments and considerable conglomerate. The detritus of which they were formed was, like that of the Chico group, derived directly from the auriferous slates. In this respect they are strongly contrasted with that of the succeeding deposits, which are composed almost exclusively of volcanic material.

Distribution and relations.—Within the Lassen Peak district there is a large area of Miocene deposits lying in the Piedmont region. One of the best exposures is on Little Cow Creek, in Shasta County, at an elevation of about twenty-nine hundred feet. At this point the creek leaves a bold, rugged cañon, cut deep into the light colored sandstone and pebbly beds, and enters upon the irregular, hummocky area that leads to the adobe land on the Chico rocks farther down stream. At the mouth of the cañon, in a fine shaly bed intercalated between the sandstone, a number of fossil leaves were found, which have been identified by Prof. Leo Lesquereux and the results are given in the accompanying list (page 420). With the fossil leaves was found a fresh-water mussel, identified by Dr. R. E. C. Stearns as *Anodonta Nuttalliana.* The horizontal strata conformably overlying the fossils are chiefly coarse sandstones occasionally containing fine gravel. They are somewhat lighter colored than the members of the Chico group and a thickness of over five hundred feet of them is exposed along the sides of the cañon. The whole series is capped by a lava flow. A few miles to the northeastward, about the head of Montgomery Creek, where the upper portion of the series is exposed, it may be seen that the sandstones pass upward into conglomerates and the volcanic material becomes more abundant near the summit of the series. At this point the strata dip slightly to the eastward away from the shore line and beneath the lavas of the volcanic ridge. A few miles down Little Cow Creek from where the fossil leaves were found, near the Oak Run road bridge, the marine shells of the Chico group were collected, and the difference in elevation of the two exposures, taken in connection with the position of the strata, suggests that there may be a great thickness of finer sandstones and shales between them. The contact between the Chico beds and the Tertiary deposits has not been observed, but their relative positions at adjacent exposures

indicate that they are slightly unconformable. The Chico beds extend about a mile up Little Cow Creek from the bridge and dip to the westward. The Tertiary deposits of the hills near by to the northward overlap the Cretaceous and dip gently in the opposite direction, so that there can be scarcely a doubt concerning the discordance of the two formations.

The Miocene formation in the Lassen Peak district, as already remarked, is composed of sandstones and shales below, and conglomerate above. The lower member is least liable to exposure, but its presence is generally indicated by a peculiar, hummocky topography quite unlike that of any other strata in the district. The small hillocks are not always round; they vary in form like the little drumlins of a glacial field and have between them small basins which in the rainy season contain lakes. That such a topographic feature is not the consequence of ordinary erosion has been remarked by many of the mountaineers, who attribute them to land-slides, and this view is supported by the fact that the hummocks are best developed where the general slope has considerable declivity. The finest examples within the district have been seen in the neighborhood of Little Cow Creek, but they were observed also near Lone Rock, south of Light Cañon, in Plumas County, as well as northeast of Coppervale, near the head of Mountain Meadows, where the same formation occurs.

The prominent ridge between Bear Creek and the South Fork of Cow Creek affords an unusually interesting exposure of the upper portion of the Miocene. At the very base of the hill, in the beds of both streams, Chico fossils have been found, so that the hill undoubtedly rests upon the Cretaceous. Above the fossiliferous beds is a considerable thickness of sandstone capped by a heavy layer of conglomerate, and overlying this is usually found a remarkable flow of tufaceous rhyolitic lava. The conglomerate at this point shows apparently a greater development than anywhere else within the district. It has been mined for gold, but without marked success. One of the miners of the region says that it contains enough fine gold to pay from 50 cents to $1 a day. The gravel has only a local development, for it is limited to the slopes of Bear Creek Hill, with a short extension eastward up the North Fork of Bear Creek, where it is mined. This linear extension east and west down the general slope and transverse to the usual strike of the Tertiary strata indicates that the gravel deposit is an old stream bed. Additional evidence in favor of the same view is to be found in the fact that in the immediate vicinity the conglomerate is absent and the overlying tufas (Pliocene) rest directly upon an eroded surface of the sandstone below.

That much of the conglomerate has been washed away is evident from the traces it has left behind. Between the Tamarack road and the North Fork of Cow Creek there is a prominent ridge extend-

ing southwesterly from the group of prominent hills about the headwaters of Burney Creek. The western terminus of this ridge is rather abrupt, and it is composed chiefly of hypersthene-andesite overlaid by basalt. High up on its slopes, lying on the andesite, are frequently found well rounded pebbles, often grouped in great abundance, but generally rather sparingly scattered over the surface. They proclaim the former presence of the Miocene conglomerate. Upon the northern side of this ridge, near the head of the cañon of the North Fork of Cow Creek, at an elevation of 3,000 feet, the conglomerate occurs in place resting upon the Miocene sandstone, which has an extensive development further westward on the divide between the North Fork of Cow Creek and Clover Creek. The pebbles on the ridge above referred to reach an elevation of 3,200 feet. Near the head of Oak Run, on the road to Silver Lake, pebbles of metamorphic rocks are scattered quite abundantly over the fresh andesitic lava up to an elevation of nearly four thousand feet. The great elevation at which these pebbles now occur may be due in part perhaps to upheaval since their deposition. These pebbles are almost wholly of quartz and other metamorphic rocks, very unlike the lavas upon which they rest. In places they appear also to overlie tufa, and it is difficult to satisfactorily explain the presence of so small a number of volcanic fragments in a conglomerate so intimately associated with the lavas.

South of Bear Creek the Miocene is not so extensively developed nor so well exposed. On the South Fork of Shingle Creek, near the prominent crater about sixteen miles directly east from Anderson, lying between the fossiliferous Cretaceous and the tufa there is but a thin body of Miocene strata. A better exposure is obtained on Ash Creek, six miles east of Ball's Ferry.

Notwithstanding the thick deposit of tufa (Pliocene) in the Piedmont region, the deep cañons cut across it by the mountain streams occasionally reach the Miocene beds upon which the tufa rests. Along Mill Creek, about twenty miles east of Tehama, where the sandstone is exposed, its upper surface was irregularly eroded before the deposition of the tufa, just as in the case already noted along the South Fork of Cow Creek.

In the cañon of Deer Creek, at an elevation of about two thousand two hundred and fifty feet, there is a remnant of an ancient stream bed of auriferous gravel, which is apparently equivalent to the Miocene conglomerate and has been extensively mined. The gravel is about thirty feet thick and is composed of well rounded pebbles less than four inches in diameter. The pebbles are chiefly of metamorphic rocks, but fragments of lava are also common. The whole is overlaid by tufa as represented in Fig. 16.

Thus far our attention has been given to the Miocene deposits of the Piedmont region within the western portion of the Lassen

Peak district. We will now turn our attention to similar deposits found outside of the district southeast of Lassen Peak, about the Mountain Meadows and in the neighborhood of Light Cañon. The formation is apparently continuous from one locality to the other, but the best exposures of it are at the place last mentioned. The northern extremity of Light Cañon opens into a basin-shaped region lying between Lone Rock and the northeastern terminus of Moonlight. This basin was once filled with Miocene lacustrine deposits, of which only a small portion now remains. The sandstone at its base has a thickness of over five hundred feet, and its horizontal beds are well exposed upon the hillsides west of Light Cañon, where they form prominent bluffs. To the east of Light Creek, near Lone Rock, the sandstone is soft and incoherent, so that instead of forming cliffs it gives rise to the peculiar hummocky topography to which reference has already been made. Fossils have not been found in the sandstone of this basin, but at the northern end of Mountain Meadows, near the main road one mile southwest of the point where it crosses the summit towards Susanville, the few fossil leaves which are

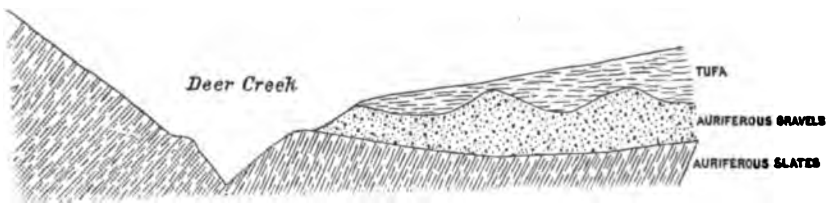

FIG. 16. Section of auriferous gravel at Deer Creek mines.

noted in the list (page 420) have been found. In both localities and at a number of intermediate points connecting the two principal outcrops the sandstone is overlaid by a heavy layer of gravel, which is occasionally cemented so as to form a very firm conglomerate. This gravel has attracted much attention, not only on account of its position, but more particularly because it is auriferous. At both ends of the Mountain Meadows it has been mined, and the work still continues during the rainy season, when sufficient water can be obtained. Within the drainage area of Light Creek the operations have been more extensive and perhaps also more profitable. Considerable money has been spent searching within the lacustrine deposits for old stream beds, which will in all probability never be found. The conglomerate or loose gravel, which has either never been cemented or else resulted from the disintegration of the conglomerate, is widespread, and reaches an elevation of nearly seven thousand feet on the very crest of the eastern escarpment of the Sierras, near Thompson Peak. The lower portion of the gravel is composed almost wholly of pebbles of metamorphic rocks. They are very smooth and well

rounded, frequently showing the ellipsoidal form characteristic of beach action.[1] In the upper portion the pebbles are larger and those of modern lavas more abundant. Excellent exposures of the upper portion of the gravel occur along the crest a few miles southeast of Diamond Peak, where it forms a prominent, smooth ridge, rising at least one hundred and fifty feet above its base. The pebbles are of all sorts. Those of quartz and of the auriferous slates and granite are generally smaller and much less abundant than those of andesitic lava, which are not infrequently two feet in diameter. A short distance north of the road, where it crosses the summit between Light Cañon and Susanville, at the head of a stream which flows into Susan Creek, the gravel is cemented into a firm conglomerate. It is about three hundred and fifty feet thick and dips slightly to the eastward. High up on the mountain side it rests directly upon the granitic rocks, but at lower levels on both sides of the mountain it is underlaid by the sandstone. Within the conglomerate are occasional thin beds and lenticular masses of shale, which are much indurated, as we shall see further on, by the orographic movements which gave birth to the Sierras. In one of these shales, less than twenty inches in thickness and of limited extent horizontally, numerous fossil leaves have been found.[2]

The fossils were determined by Prof. Leo Lesquereux, whose results will be found in the appended list (p. 420).

While examining the general structure of the Sierras in the vicinity of Indian and American Valleys I had an opportunity to visit the summit of Spanish Peak and collected some fossils from the aurife-

[1] Normal wave action on a beach rolls the pebbles back and forth about the same axis and tends to produce out of cubical blocks of homogeneous stone ellipsoidal pebbles. As a rule the pebbles of a beach are not ellipsoidal, but this is due to the fact that the direction of wave motion is inclined to the coast and to irregularity of the initial form and want of homogeneity in the material. Rocks frequently split in one direction much more readily than in any other, and thus give rise to flat fragments. Their flatness is increased by beach action, because they do not roll but slide back and forth.

[2] On account of the importance and scarcity of fossils in that region their position should be more definitely described. They occur in Lassen County, about three-fourths of a mile north of the point where the Light Cañon and Susanville road crosses the summit. The surest way to reach the exposure is to start from the first small bridge, one-fourth of a mile below the summit on the Susanville side, and go up the gulch almost directly west for a few hundred yards to the summit of a partially bare ridge. Cliffs of conglomerate appear on the left (south side) as the summit is approached. The ridge or rather spur extends northerly and upon its sides soon appear two deep, precipitous, rocky gulches which unite about a quarter of a mile below. More than half way down the spur on its northwesterly slope, in an open space about fifty feet above the bottom of the gulch, the very limited exposure may be found. My attention was called to this interesting locality by Mr. W. C. Kingsbury, of San José, Cal., who discovered these fossils while prospecting for gold thirteen years ago.

rous gravels of the Monte Christo mine.[1] The gravel mined at this place is doubtless closely related to that at Lot's Diggings, about twelve miles to the northwest and high up on the opposite side of the cañon of the North Fork of Feather River. The gravel is very smooth and round, just like that of the lacustrine deposits east of Indian Valley, but, unlike the latter, it appears to belong to a stream bed. The form of the deposit appears to be linear and confined to a definite channel, which is from one hundred to six hundred feet in width at the surface and about four hundred feet deep. The upper portion of the deposit is chiefly gravel and the lower part distinctly stratified, fine, argillaceous sand or clay (pipe clay), which at some places rests directly upon the granite, at others is underlaid by conglomerate. The fossils were found at a distance of nearly three thousand feet from the mouth of the tunnel and approximately two hundred and seventy-five feet below the surface, in the clayey strata. They occur in great numbers and can be obtained in an excellent state of preservation, but the bed containing them is so soft as to readily disintegrate. Besides the leaves noted in the list of determinations by Professor Lesquereux (p. 420), a fossil fresh-water fish[2] was found in the same bed.[3] The form and structure of the deposit indicates that it is fluviatile, like the great mass of the auriferous gravels on the western slope of the Sierras described by Prof. J. D. Whitney[4] and others; but what relation it holds to the lacustrine deposits to the northeastward has not yet been determined. The character of the pebbles is such as to suggest that they may have been derived from the lacustrine deposits, but there are other considerations which suggest for them a greater antiquity. At Cherokee, for example, in the mine of the Spring Valley Hydraulic Gold Company, the auriferous gravels are overlaid by several hundred feet of fine conglomerate and soft sandstone, which have furnished

[1] I am greatly indebted to Mr. Malcolm Matheson, superintendent of the mines, not only for much valuable information, but also for guiding me through the extensive series of underground passages in the mine and rendering efficient service in the collection of fossils.

[2] It was examined by Prof. W. H. Dall, who reports that "the fish appears to have had no scales; the teeth were so small, if any, that they have left no traces on the impression. The dorsal and ventral fins are evidently more or less imperfect, and the tail is altogether wanting. The form of the anterior extremity of the pectoral fin, the lateral tine, and the remaining indications of the posterior fins agree fairly well with those of *uranidea*, a genus of small fresh-water cottoids which are particularly abundant at the present day in the streams of California. At all events the opinion may be expressed with some confidence that the fish was not marine and that it was related to *uranidea*."

[3] The fossil fish was found several years ago by Mr. J. G. Phelps, who has kindly donated it to the National Museum of Washington, D. C.

[4] The auriferous gravels of the Sierra Nevada of California: Memoirs of the Museum of Comparative Zoölogy at Harvard College, vol. 6, No. 1, 1883.

a few leaf impressions[1] to indicate that the deposits belong to the Miocene fresh water lacustrine beds so extensively developed in the Piedmont region. It is evident that the auriferous gravels underlying these deposits belong to an early portion of the Miocene or to the Eocene.

Fossils found in the Miocene strata.—The following tabular view gives a list of all the plant remains found in the formation just described. The figures indicate the number of specimens of each species found. All of the determinations were made by Prof. Leo Lesquereux, who has furnished the following statements concerning their geological relations:

"*Juglans Bilinica* is found along Little Cow Creek and upon Spanish Peak, while *Phragmites Oeningensis* occurs at both of the other localities. The most abundant form, *Persea Dilleri*, is related to the living species *Persea Carolinensis*, variety *palustris*, of our south Atlantic border, and occurs both along Little Cow Creek and near the summit north of Light Cañon.

"Two species, *Magnolia Hilgardiana* and *Quercus Moorei*, are identified in the Eocene of the Mississippi; and two others, *Aralia Lasseniana* and *Oreodaphne litsœœformis*, are related to the Eocene (Sézanne and Gelinden) of France and Belgium.

"Seven species are identified in the Miocene of North America, viz: *Platanus dissecta*, *Laurus Californica*, *Cornus hyperborea*, *Pterospermites spectabilis*, *Quercus Olafseni*, *Laurus socialis*, *Juglans rugosa*.

"Five species are identified in the Miocene of Europe: *Myrica Ungeri*, *Juglans Bilinica*, *Phragmites Oeningensis*, *Oreodaphne Heeri*, and *Cinnamomum Scheuchzeri*.

"Three species have been identified with those of the auriferous gravels of California, viz: *Ficus microphylla*, *Magnolia Californica*, and *Platanus dissecta*. These three, with *Cornus Kelloggi* as closely related to *Cornus hyperborea* and to the living *Cornus Nuttalli* of California, represent the recent forms of plants described above. The relation is therefore evidently to the Miocene."

Prof. Lester F. Ward, who not only saw the fossils but also examined the list of species, determined by Professor Lesquereux, expressed the opinion that the strata from which they were taken, as well as the auriferous gravels, the upper portion of the John Day group, with those at Corral Hollow and perhaps the Bellingham Bay beds, all belong to the same series, and he agrees with Professor Lesquereux that they are Miocene, most likely Upper Miocene.

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[1] See Prof. L. F. Ward's report in Bull. U. S. Geol. Survey, No. 33, 1886, p. 16.

List of fossil leaves determined by Prof. Leo Lesquereux.

Species.	Little Cow Creek, Shasta County, Cal.; elevation, 2,900 feet.	Northeastern corner of Mountain Meadows by main road, 1 mile southwest of where it crosses summit towards Susanville, Lassen Co., Cal.; elevation, 5,000 feet.	Three-quarters of a mile north of where Light Cañon and Susanville roads cross the summit, Lassen Co., Cal.; elevation, 6,000 feet.[1]	Monte Christo mine, near summit of Spanish Peak, Plumas County, Cal.; elevation, 6,350 feet.
Acer Bendirei Lx				4
Alnus Kefersteini Al. Br	1			
Alnus nostratum ? Heer			1	
Aralia Lasseniana, sp. nov., Lx			1	
Asplenium Wegmanni ?			2	
Cinnamomum Scheuchzeri or polymorphum, Al. Br		1		
Cornus hyperborea ? Heer			1	
Ephedrites Sotzkianus ? Schp			1	
Ficus appendiculata ? Heer			1	
Ficus microphylla Lx	1			
Ficus Shastensis, sp. nov. Lx., related to F. scabriuscula Heer	3			
Juglans Bilinica Ung	2			1
Juglans rugosa Lx			1	
Laurus Californica Lx				1
Laurus socialis Lx			3	
Leguminosites ? species			1	
Magnolia Californica Lx			2	
Magnolia Hilgardiana Lx			1	
Magnolia Inglefieldi Heer			10	
Myrica Ungeri Heer				1
Oreodaphne litsææformis, sp. nov., Lx			1	
Oreodaphne Heeri			1	
Persea Dilleri, sp. nov., Lx., related to P. Caroliniana var. palustris Chap.	9		1	
Phragmites Oeningensis Al. Br		3	2	
Platanus dissecta Lx				3
Pterospermites spectabilis, Heer				1
Quercus Moorei Lx			4	
Quercus Olafseni ? Heer			1	
Rhus ? species	3			

Hypsographic and climatic conditions during the Miocene.—During the Miocene the northern portion of the Sacramento Valley was occupied by an extensive fresh-water lake, which stretched far to the northeastward through Lassen Strait, that marks the limit between the northern terminus of the Sierras and the Coast Range and is now occupied by the volcanic ridge of Lassen Peak. A similar body of water existed northeast of Indian Valley, in the country now occupied by the very crest of the Sierras, northwest of Honey Lake, at an elevation of nearly seven thousand feet. From the fact

[1] In Proc. U. S. Nat. Museum, 1888, p. 28, the age of the fossils from this locality is stated to be Eocene (Laramie).

that the lacustrine deposits on both sides of Lassen Peak pass beneath its lavas, it is believed that they are continuous and were all laid down in the same lake, which at that time covered a large portion of what is now the northern end of the Sierras and extended from the Sacramento Valley far into Oregon. Mr. Clarence King[1] has called attention to the wide distribution of Miocene lacustrine deposits in that region, extending from beyond the Columbia River south, through Oregon into Nevada and California, and it may now be added that they pass through the gap separating the north end of the Sierras from the Coast Range into the northern portion of the Sacramento Valley. To the large body of fresh water in which these sediments were found King gave the name Piute Lake. The Piute Lake deposits reach much farther up on the flanks of the Sierras than the littoral deposits of the Chico epoch, indicating clearly that between the close of the Chico epoch and the beginning of the Miocene there was a change in the relative elevation of the Sacramento Valley and the Sierra region. This change was effected by the elevation of at least part of the region of the Coast Range, and apparently also of the Cascade Range, so that the oceanic waters were excluded and the formation of Piute Lake was rendered possible. That this elevation occurred at the close of the Cretaceous is rendered altogether probable by the fact that the Tejon group has not yet been recognized within the Piute Lake region. Perhaps we may yet find in the earlier deposits of that lake the fresh-water equivalents of the Tejon group of western Oregon and southern California.

The distribution of the lacustrine deposits in the Mountain Meadows region can not be well illustrated until the cartographic work of that district has been completed. Their relations, however, appear to fully justify the statement that at the time they were deposited the country to the eastward was higher than the region now occupied by the Sierras, at least in the latitude of Diamond Peak. Furthermore, if these deposits were, as we suppose, all laid down in the same lake, it is evident that during the Miocene the sediments which now form the eastern crest of the Sierras near Diamond Peak must have been on about the same level with those of the Sacramento Valley.

In answer to my question concerning the climatic condition of that region during the Miocene, as indicated by its flora, Professor Lesquereux states that "by the presence of a large number of *Laurineæ* the flora becomes related in its general characters to that of a region analogous in atmospheric circumstances to Florida." With this view Prof. Lester F. Ward also fully agrees, and it is in complete harmony with the inference drawn from structural relations, viz; that during the Miocene that country was a broad platform, with

[1] U. S. Geol. Exploration of the 40th Parallel, vol. 1, 1878, pp. 451–454.

gentle relief, and but moderately elevated above the sea; or, in other words, the surface of the region was but little above its base level of erosion.

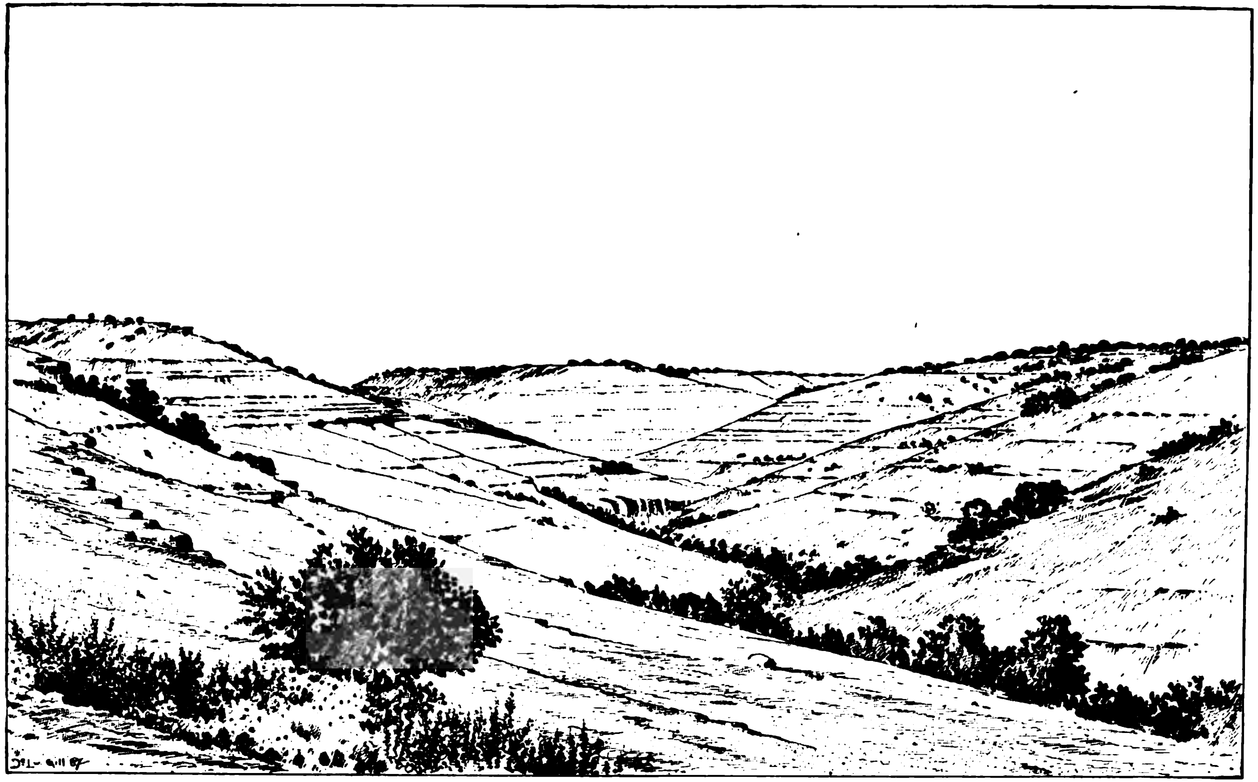
PLIOCENE.

Within the Lassen Peak district deposits of Pliocene age have not been definitely distinguished from those of the Miocene, but their presence is rendered altogether probable by several considerations. The auriferous gravels were regarded by Professor Whitney as accumulating upon the western slope of the Sierras throughout the whole of the Tertiary, reaching their culmination in the Pliocene. This view is very probable, indeed; for, although the mass of the gravels of the gold belt are Pliocene, it appears to be evident that other portions, especially that at Cherokee as well as about Mountain Meadows and near the head of Light Cañon, belong to the Miocene.

Overlying the Miocene of the Piedmont region is a very extensive development of the volcanic tufas. As already remarked, in the upper portion of the Miocene conglomerate, especially in the region of Bear Creek, Diamond Peak, and Mountain Meadows, pebbles of lava become abundant; in fact, they rapidly increase upwards, so as to completely predominate, and the formation passes into tufa without any apparent stratigraphic interruption. It has been completely demonstrated by Whitney, Le Conte, and others that in the Sierras the great volcanic outbreak took place in the Pliocene, and there is reason to believe that the early eruptions in the Lassen Peak district, which gave birth to the immense mass of tufa in the Piedmont region, occurred about the same time. The tufas were unquestionably deposited later than strata known to be Miocene, and earlier than the Quaternary, so that we feel constrained to regard them as belonging to the Pliocene.

This formation has its greatest development in the southwestern quarter of the Piedmont region and determines its peculiar features. All of the mountain streams between Battle and Butte Creeks on their way to the Sacramento have cut deep cañons across the Piedmont, and thus furnish excellent exposures of the tufa. Its genesis is a very perplexing problem.

The material of which it is composed is chiefly hypersthene andesite, but fragments of hornblende andesite and basalt are also common. Much of the detritus has been subjected to considerable water attrition, so as to appear in the form of rounded pebbles or sand; but the larger portion, ranging in size from fine dust to blocks of lava several feet in diameter, is rough and angular without distinct traces of abrasion. In the cañons where the tufa is well exposed it may be observed that much of the material is assorted and distinctly stratified. The accompanying illustration (Pl. XLVIII), which represents its general features very well, was taken near the western



CAÑON OF LITTLE DRY CREEK, SHOWING THE STRATIFIED TUFAS OF THE PIEDMONT REGION.

limit of the Piedmont, northeast of Tehama. It is true that in many places a stratum of material apparently thrown together pell-mell may be so large as to create the impression that the whole mass is without arrangement, but this is not the case. Much of the sediment has been picked out and laid down in such a way as to clearly indicate that its deposition took place in water. In the cañon of Mill Creek and also in that of Deer Creek, near the mountains, where the tufa has a thickness of nearly one thousand feet, it is roughly divisible into three parts, as indicated in Fig. 17. The upper and lower portions are agglomerate and between them the stratified arrangement of the tufa is clearly discernible. In all parts the sediments are essentially the same, being composed largely and perhaps chiefly of fragmental material ejected from volcanoes.

The peculiar manner in which the tufa was formed is an enigma whose complete solution has not yet been attained; nevertheless there are some conditions attending its formation which we may understand. The aqueous stratification of a large part of the tufa appears to me to be evident, and the body of water in which it was laid down filled the northern end of the Sacramento Valley. Piute Lake, with modifications, may have continued into the Pliocene. At any rate, it is apparent that the water body about the northern terminus of the Sierras during the Pliocene was shallower and more extensive than the Miocene Lake, and differed also in the character of its deposits. The distinctly assorted material is of two varieties: (1) That which has been considerably abraded and was produced by normal shore agents, and (2) that which was ejected during violent volcanic action and after being wafted for a considerable distance by the winds fell into the water.

The agglomerated portion of the tufa is complicated in its genesis, and probably received additions in various ways. Most important of these along its eastern margin was the tumultuous contribution from the active volcanoes near shore.

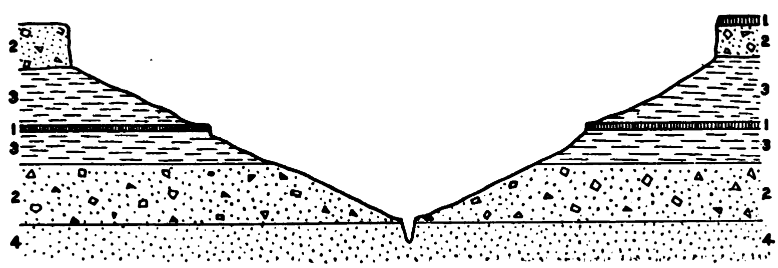


FIG. 17. Mill Creek Canon, 20 miles east of Tehama: Depth 1000 feet. 1. Basalt. 2. Agglomerated tufa. 3. Stratified tufa. 4. Yellowish sandstone.

Intercalary lavas such as are shown in the section (Fig. 17) are not uncommon, and by irregular decomposition and disintegration they

frequently give rise to pseudo-agglomerates which may closely resemble real agglomerate in general aspect. They may be readily distinguished from the latter, however, by the uniformity of their composition throughout both matrix and fragments.

A large part of the pell-mell beds are heterogeneous in composition, and contain large angular fragments of compact lava, which bear no marks of having ever been ejected from a volcano, but appear rather to have been driven from their parent bed in the process of secular decay.

The manner in which superficial lava flows may be broken up by atmospheric influences and the angular fragments strewn over the plain is well illustrated by several examples in the Piedmont region, especially in the vicinity of Paine's Creek. This process is evidently subaërial and is doubtless accompanied to some extent by the sort of action which gives rise to alluvial cones. The cause which produces alluvial cones is the main one to which Captain Dutton appealed to explain the accumulation of the enormous detrital masses of volcanic rocks in the high plateaus of Utah,[1] and it has probably contributed to the upbuilding of the Piedmont region; but the greater influence in the development of its peculiar features must be ascribed to the Pliocene lake which occupied the northern part of the Sacramento Valley.

The topographic features which always accompany the degradation of heavy beds of agglomerate are often prominent, and enable the observer to recognize the formation at a considerable distance. They usually present either cliffs or irregular columns scattered promiscuously and abundantly over the slopes.

The plain of the Piedmont region is often extremely stony. The rough, angular fragments strewn over the surface in great numbers are in part the surviving pieces of a once continuous lava sheet, and in part the enduring portions of the disintegrating agglomerate, the finer material having been removed. A typic example of this sort of stony waste may be seen eight to twelve miles east of Red Bluff, south of Paine's Creek, on the Susanville road. The dreary plain is often for wide stretches without arboreal vegetation; but the stunted oak (*Quercus Garryana*), taking hold below, and the bull pine (*Pinus Sabiniana*) with the manzanita and other shrubbery above, mitigate its otherwise complete barrenness. The traveler over the desolate Piedmont region is not likely to forget its peculiarities, especially if he crosses it in an open conveyance under the blaze of a summer sun. It fits him to enjoy the salubrity of the mountain clime beyond, and it makes him feel that he has earned an abode for a time in the garden of the Hesperides by having successfully passed through Pandemonium.

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[1] Geology of the high plateaus of Utah (Capt. C. E. Dutton), 1880, p. 77

VIEW OF THE PIEDMONT BLUFF FROM THE SACRAMENTO VALLEY.

Lassen Peak volcanic ridge in the distance.

UPHEAVAL OF THE PIEDMONT REGION.

That the tufa of the Piedmont region was deposited near the shore of a large body of water which occupied the northern portion of the Sacramento Valley is apparently certain, and that the water was fresh is inferred from the fact that it appears to have been a continuation of the fresh-water Miocene lake. It is evident that the champaign character of the formation was determined by the water in which the deposition took place. Some time after the deposits were formed they were raised above the lacustrine waters in such a way that the mountain streams run directly across them and each stream excavated for itself a deep cañon. The uplifting was differential, being greatest to the eastward, so as to give the plain a westward declivity of about four degrees. At the same time the western limit of the region was defined by the development of an interesting monoclinal fold, which is exposed in the gates of all the cañons where the streams debouch into the Sacramento Valley proper. It gave rise to the prominent bluff which is well illustrated in the following view (Pl. XLIX), taken from the Sacramento Valley opposite the gate of Mill Creek. The bluff is here over a hundred feet high. Across the Piedmont region, at a distance of about twenty miles, the volcanic ridge of Lassen Peak is conspicuous. A section of the monoclinal fold south of Antelope Creek is given in Fig. 18, and

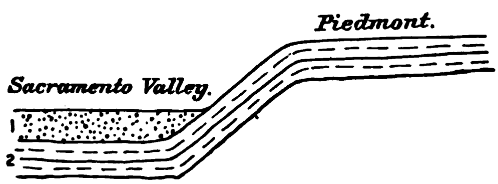


FIG. 18. Section of the Piedmont monocline near gate of Antelope Creek. 1 Quaternary gravels. 2. Volcanic tufa (Pliocene?).

shows the relation of the tufa of the Piedmont region to the Quaternary gravels of the Sacramento Valley. This monoclinal fold extends from the neighborhood of Battle Creek on the north beyond Deer Creek, gradually dying out at both ends, so that the Piedmont region beyond the limits of the fold continues its gentle slope without interruption to the level of the Sacramento Valley. The displacement along the monoclinal fold is on an average somewhat more than one hundred feet and was formed before the deposition of the Quaternary. At that time the cañons were already cut across the Piedmont, and the streams entered the Sacramento Valley at the level of its alluvial plain, to which each creek contributed a low, deltoid, gravel cone.

Within the cañon of Deer Creek, as also in that of Mill Creek already illustrated (Fig. 17), there is a small cañon containing the present stream. It is best developed near the gate of Mill Creek,

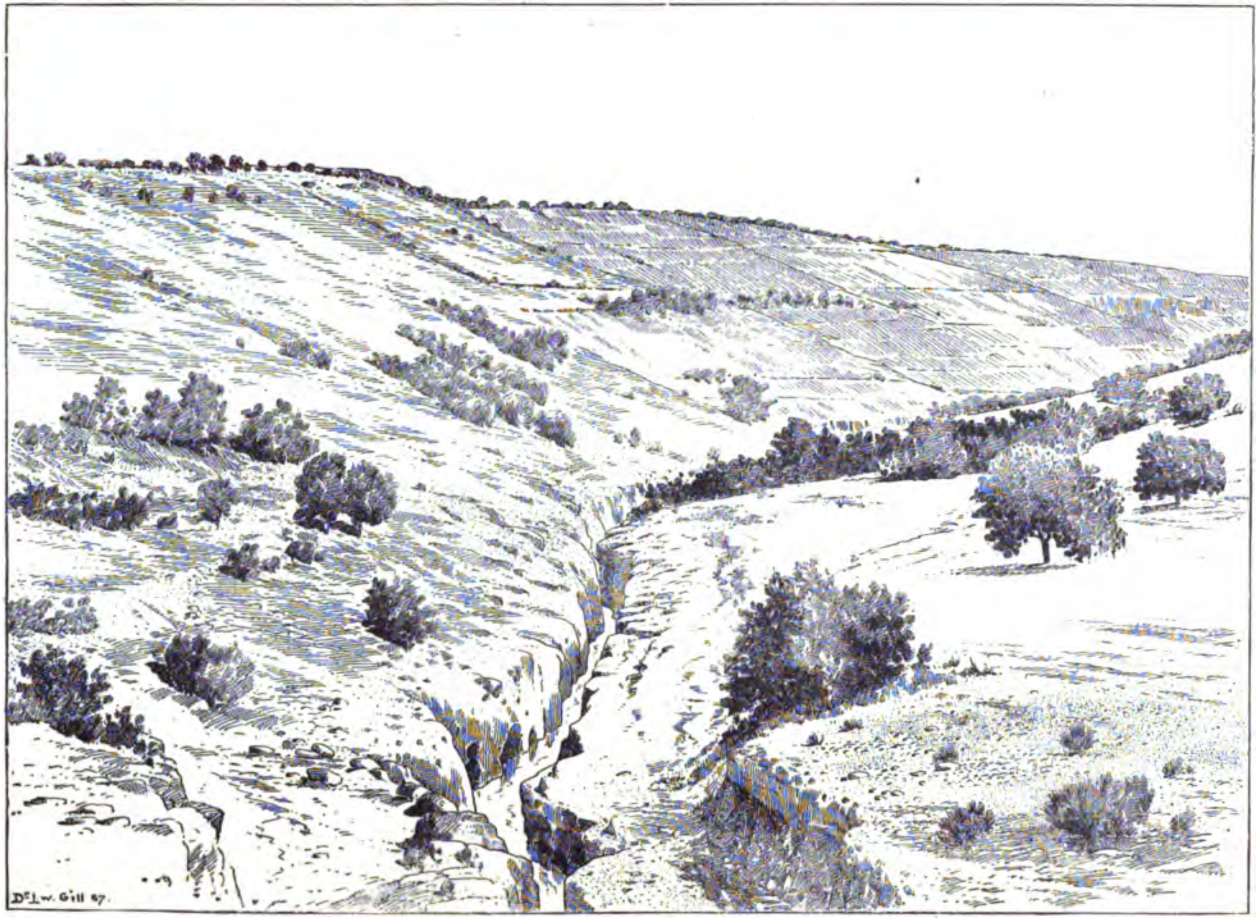
where the annexed view (Pl. L) was taken. The depth is frequently over seven times its width, and it extends out into the valley gravels for more than a mile. It is evident that this secondary cañon is due to the differential uplifting of the Piedmont region, by which the declivity of the stream was so increased as to augment the corrasion upon its restricted bed and in the same proportion to diminish the wearing away of its banks. The relation of the valley gravels to the Piedmont bluff, and the fact that the younger cañon extends some distance out into the Quaternary deposits indicate that the latest uplifting in that region, which gave birth to the little cañon, was post-Quaternary, although the formation of the monocline took place at the close of the Pliocene.

STRUCTURE OF THE SIERRAS..

That the development of the Sierras and their relation to the volcanic ridge of Lassen Peak may be more readily understood, some of the more salient structural features of the northern portion of the range will be briefly considered. It has a width of about eighty miles, extending from the Sacramento Valley to Honey Lake, and has three distinct crests which are characterized by long, gentle slopes to the southwest, and short, abrupt ones in the opposite direction, as shown in Fig. 19. The western crest, to which Claremont

FIG. 19. Section from Honey Lake to Sacramento Valley. 1. Granite. 2. Auriferous slates. 3. Carboniferous limestone. 4. Quaternary, or recent deposits. 5. Faults.

Hill and Spanish Peak belong, is near the middle of the range, and attains an altitude of about seven thousand feet. From this point the long, gentle slope extends to the Sacramento Valley, at an elevation of less than three hundred feet above the sea. It is more or less undulating and deeply cañoned by numerous streams. From Claremont Hill the slope is abrupt towards American Valley, which at Quincy has an altitude of 3,375 feet. Continuing to the eastward the slope again rises more gently 7,300 feet to the middle crest, in which Hough's Mountain is a prominent feature, and then descends steeply, as in Pl. LI, to Indian Valley, at an elevation of about thirty-five hundred feet. Farther on the topography is irregular, but becomes an even slope, rising to 6,000 feet in the summit of the eastern crest, the bold escarpment overlooking Honey Lake. The outline of the Sierra Nevada Range, as seen in cross-section, is such as to at once suggest that, like the basin province, it is composed of tilted orographic blocks, which are separated from one another by faults. The fact that Indian Valley and American Valley, which are the depressions between the crests of the range, were occupied



VIEW SHOWING THE RELATION BETWEEN OLDER AND YOUNGER CAÑONS OF MILL CREEK.
Eight miles east of Tehama.

by lakes during the Quaternary or later times greatly heightens the analogy.[1]

The recurrence of the same fossiliferous strata in a cross-section of the Sierra Nevada Range in exactly analogous topographic and stratigraphic positions confirms the hypothesis suggested by the profile that the northern end of the Sierra Nevada Range is made up of three orographic blocks separated from one another and from those of the Great Basin by profound faults, and shows that the basin range structure extends as far west as the Sacramento Valley. Mr. G. K. Gilbert[2] several years ago pointed out the characteristic features in the structure of the Sierra Nevada Range. Prof. Joseph Le Conte[3] had previously called attention to a profound fault along its eastern base in the vicinity of Owen's Lake, and has since published a most interesting contribution[4] on a post-Tertiary elevation of the Sierra Nevada shown by the river beds.

By far the greater portion of the range appears to be formed of one great orographic block, which is continuous with the western block of the range at its northern termination. Its long, gentle slope westward is expressed in the drainage lines, and its eastern crest is the divide between the Great Basin and the Pacific. Almost throughout its whole extent the Sierra Nevada faults of greatest dimensions are impassable to important streams except at the northern end of the range, where the number of fault blocks is increased. The forks of Feather River cross two of the prominent lines of displacement. These streams, like nearly all those that flow down the western slope, are in deep cañons. That of the North Fork of Feather River, where it crosses the western fault, has a depth of 4,000 feet, affording an excellent section of the folded strata, and its terraces indicate the character of the uplifting in forming the mountain range.

Structurally the Sierra is like the Great Basin range, differing chiefly in the magnitude and the present elevation of the blocks. Like the orographic blocks of the Great Basin area, they are composed of plicated strata, the folding of which, as has been pointed out by a number of observers, took place long before the faulting that gave birth to the peculiar features of the range. It is important to remember the fact that at the time the strata of which the Sierra is composed were folded (i. e., about the limits between the Jurassic and Cretaceous periods) the range was not differentiated from the continental mass of the Great Basin region, and it was not until a very much later period that this separation occurred.

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[1] For remarks upon the stratigraphy of the orographic blocks, see Bull. U. S. Geol. Survey, No. 33, pp. 12–15.

[2] Science, vol. 1, 1883, p. 195.

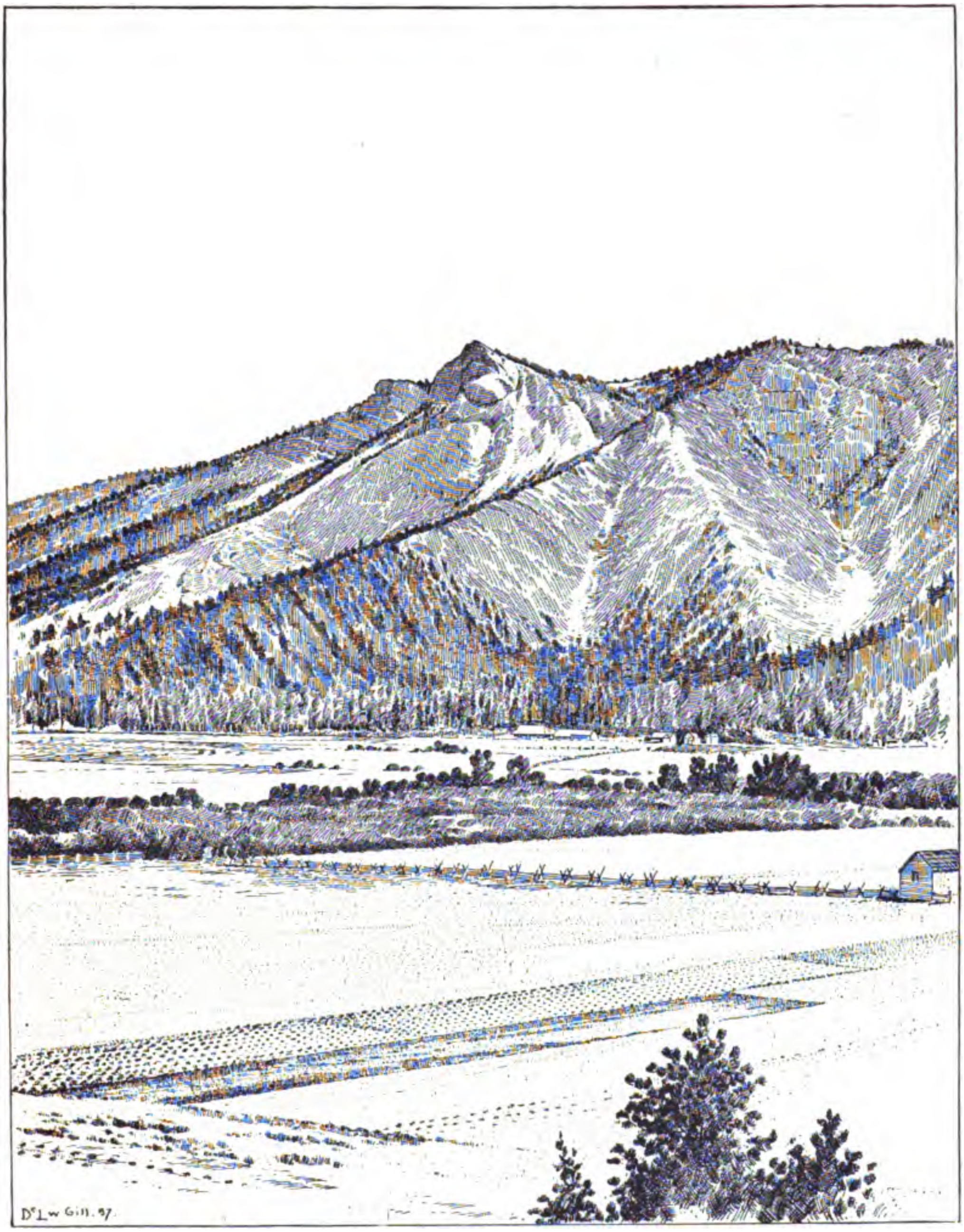
[3] Am. Jour. Sci., 3d series, vol. 16, 1878, p. 101.

[4] Ibid., vol. 32, 1886, p. 167.

It must not be imagined that the structure of the Sierra is really as simple as it appears in Fig. 19; for, as already stated, the auriferous slates and numerous eruptive masses of which the orographic blocks are composed are not only folded in a very confusing manner, but are greatly complicated also by a large number of recent faults. The uplifting of the Sierras resulted in the increased declivity of their western slope and caused the streams more and more vigorously to corrade their beds. Each successive uplift increased the corrasion and restricted the stream to a narrower channel, leaving terraces upon the slopes of the cañon to mark the time of the uplifting. Thus it happens that the western slope, once gentle and flooded by Pliocene streams, is now deeply furrowed by terraced cañons.

RELATION OF THE UPLIFTING AND FAULTING OF THE SIERRAS TO EACH OTHER AND TO VOLCANIC PHENOMENA.

The relation of the uplifting of the Sierra Nevada Range to its volcanic activity and faulting is one of the most important problems that the district affords, and its solution can not be fully attained until the detailed survey of districts adjacent to that of Lassen Peak is complete. During the whole of the Cretaceous and the Tertiary the great belt of country lying east of the present Sacramento Valley embracing the region now occupied by the Sierra, and a large portion of the Great Basin, was above the sea, and subjected to great degradation, which reduced it almost to its base level of erosion. This gentle plain swept westward toward the ocean directly across the site of the present Sierra. That the north end of the Sierra country was a lowland during the Miocene, as already shown, is rendered perfectly evident by the character of its flora; and the relation of the Miocene conglomerate to the eastern escarpment north of Honey Lake is such as to demonstrate that during the Miocene the Sierras were not yet in existence. Similar conditions continued through the Pliocene, for the Pliocene gravels on the western slope of the Sierras were evidently deposited while its inclination was very gentle, before the Sierra region had attained any considerable elevation, and apparently also while it was yet a part of the Great Basin platform. The long continued repose of that region was terminated by the development of vigorous volcanic activity, accompanied by extensive upheaval. That these two phenomena developed contemporaneously is made plain by the relations of the volcanic products to the Pliocene and Quaternary river channels. It is well known that the Pliocene channels were filled with volcanic débris and lava flows to such an extent that the streams had to seek new channels. The differential uplifting which accompanied the volcanic outbursts greatly increased the erosive power of the streams, and the result is to be seen in the deep cañons which they have cut down the western slope of the Sierras, leaving the ancient beds of the Pliocene streams



HOUGH PEAK, LOOKING SOUTH ACROSS THE WESTERN PORTION OF INDIAN VALLEY.

on the divides far above the present water ways. That the uplifting of the Sierras was not all accomplished at once but by a succession of upheavals separated by considerable intervals of time is evidenced by the traces of stream terraces which can be detected along the slopes of the cañons. These have the same origin as that already considered in describing the Piedmont region (page 426), and are undoubtedly due to successive increase in the declivity of the western slope produced by differential elevation. Now, it not infrequently happens that the lava erupted at the time of the uplifting has flowed down a cañon and capped the terrace formed at that time. That the terrace is due, not to the lava flow, but to the upheaval, is readily perceived by following the flow to its lower extremity, where the terrace upon which the lava rests will be found to continue far beyond the lava stream itself. While it can not be demonstrated that each volcanic eruption was accompanied by a corresponding elevation, it appears to be generally true that each great upheaval was accompanied by volcanic outbursts. Numerous examples of the contemporaneity of upheavals and volcanic effusion indicate that they may be casually connected.

The faulting by means of which the Sierra Nevada Range was separated from the Great Basin platform took place, in a geologic sense, very recently. The eastern escarpment of the range, at least in its northern portion, was evidently formed after the conclusion of the volcanic activity in its immediate vicinity. Attention has already been called to the displacement of very recent lavas along the crest north of Honey Lake. Opposite Janesville, on the very brow of the eastern escarpment, is Thompson Peak, which is half of a crater cone cut in two by the fault; the other half has fallen away. The bedded tufas of the elevated remnant of the cone are a very conspicuous topographical feature on the crest, and their relation to the displacement is unmistakable. Thompson Peak was an active volcano during a very late geologic epoch, so recent indeed that notwithstanding its destructibility and exposure it has suffered comparatively little from erosion. Farther northward along the same crest other new basaltic flows have been profoundly dislocated in the same manner. The great mass of gravel which forms a smooth, barren ridge on the crest southeast of Diamond Peak was evidently formed before the faulting occurred. Its upper portion is composed chiefly of pebbles of modern lavas, indicating clearly that the volcanic activity antedated the dislocation. I have searched in vain along the eastern escarpment north of Honey Lake for volcanic material the eruption of which succeeded the faulting.[1]

The great fault which lies along the western side of American

[1] In the vicinity of Lake Mono, however, and perhaps also at other points along the eastern base of the Sierras, there has been very recent volcanic activity, apparently subsequent to the displacement.

Valley continues northwesterly with irregularities into the modern lavas about the head of Butte Creek. At a number of other points north and east of Big Meadows there are lines of dislocation parallel with those of the Sierras and probably formed at the same time. They intersect some of the latest lava flows of that region and were evidently developed long after the volcanic activity had passed its maximum. Not a single example has been found of the escape of lava through a fault fissure.

This subject will be more fully discussed at another time, while considering in detail the volcanic phenomena of the Lassen Peak district. Enough has been said to make it evident that the volcanic activity upon the northern end of the Sierras occurred at the time of their upheaval and that the faulting and subsidence of the Great Basin region which individualized the range took place at a later date.

RECAPITULATION.

The primary relief features of the district are the Great Basin platform upon the east, the Piedmont region upon the west, and the Lassen Peak volcanic ridge in the middle. To the southeastward this ridge appears to merge into the Sierras, and in the opposite direction to unite with the Coast Range, but in reality it is simply an accumulation of lavas occupying a depression between these ranges and belongs geologically to the Cascade Range.

The stratified deposits, excepting the most recent lake beds, lying for the most part beneath the lavas belong to three groups, the auriferous slates, the Cretaceous member of the Chico-Tejon series, and the Tertiary, including both Miocene and Pliocene.

The auriferous slate series, which embraces both massive and water-laid rocks, occupies two areas at opposite extremes of the district, one in the vicinity of the North Fork of Feather River and the other near Pit River. The former is at the northern terminus of the Sierra Nevada Range, where the gold-bearing rocks are extensively developed, and the latter is at the end of the eastern extension of the Coast Range. Between these two exposures there is a great depression in the auriferous series transverse to the general trend of the Sierras. This depression marks the boundary between the northern end of the Sierras and the Coast Range, and from the latter portion of the Cretaceous to the Pliocene, inclusive, was occupied by Lassen Strait, which filled it with sediments.

Among the auriferous slates there are large masses of serpentine which have resulted from the alteration of peridotites, in some cases so rich in olivine that they may be classed with the dunites.

Concerning the age of the auriferous series it may be said that, as it becomes more and more evident that a large part of the auriferous slates is Mesozoic, so also the evidence is accumulating in favor of

the view that another large portion of them is older than the limestone and possibly pre-Carboniferous.

The Chico beds laid down as marine sediments are the most ancient, unaltered, stratified rocks known in the district and repose discordantly upon the plicated auriferous slates. They occupy the great central valley of California and, extending through Lassen Strait, connect with a large mass covering a wide expanse in eastern Oregon. During the Chico epoch the Lassen Peak district lay almost wholly within Lassen Strait, which separated the large Cretaceous island of northwestern California from the continental land to which the Sierra country belonged.

Some time between the close of the Chico epoch and the beginning of the Miocene there was an upheaval west of the Sacramento Valley, and also apparently in the vicinity of the Cascade Range. The oceanic waters were thus excluded from the Sacramento Valley, Lassen Strait, and a large area in eastern Oregon, for we find that the whole region of Upper Cretaceous marine sediments was covered during the Miocene by a great body of fresh water, to which the name Piute Lake has been given. Whether the transition from marine to fresh water conditions was direct or, as at other places, through a series of intermediate brackish water stages, is as yet only conjectural. Positive evidence concerning the history of the district during the latter portion (Eocene) of the Chico-Tejon period has not been clearly made out, but it may be surmised that if the moderate upheaval which gave birth to Piute Lake occurred at the close of the Chico epoch the equivalent of the marine Tejon deposits may be looked for in the lower portion of the Piute Lake beds.

Before the Miocene there was a change in the relative elevation of the Sacramento Valley and the Sierra region, because the shore deposits of Piute Lake are found farther up on the slopes of the Sierras than those of the Chico group. This change was doubtless a part of the result brought about by the movement which raised the Sacramento Valley above the sea level and prepared the slightly unconformable surface for the Piute lake deposits.

The relations of the Miocene lacustrine deposits appear to fully justify the statement that at the time they were laid down part of the Great Basin country was higher than the region now occupied by the Sierras, at least in the latitude of Diamond Peak. During the Miocene that country was a broad platform, with the gentle relief that indicates a near approach to its base level of erosion. The evidence drawn by paleobotanists from the plant fossils found in the Miocene strata strongly corroborates this view. They have compared the climatic conditions of that country during the Miocene to those of a country like Florida.

The Miocene conditions appear to have continued into the Pliocene, at least as far as Piute Lake is concerned, and to have finally ter-

minated in a great revolution which gave to the country its present aspect.

The extravasation of massive rocks occurred at various intervals in the geologic history of northern California, but the final great volcanic outburst reached its maximum near the close of the Pliocene and continued with gradually declining vigor almost to the present day.

The upbuilding of the Lassen Peak volcanic ridge was effected by these outbursts, and at the same time birth was given to the material from which the Piedmont region was developed at the close of the Tertiary. This material was deposited chiefly under the influence of lacustrine waters, and upheaved bodily in such a way as to produce a monoclinal fold and bluff which marks the western limit of the Piedmont region.

Since the deposition of the Quaternary gravels of the Sacramento Valley there has been a differential uplifting of the Lassen Peak district, by which the streams crossing the Piedmont have been enabled to cut small cañons within the larger ones of pre-Quaternary corrasion.

Gentle slopes prevailed during the deposition of the Pliocene gravels. The uplifting of the Sierras took place for the most part at the close of the Pliocene, and was accompanied by the manifestation of great volcanic activity.

The profile of a cross-section of the Sierras and the recurrence of the same fossiliferous strata in analogous topographic and stratigraphic positions demonstrates that the northern end of the range is made up of three orographic blocks separated from one another and from those of the Great Basin by profound dislocations. These displacements occurred chiefly if not wholly after the elevation of the Sierras, when the volcanic energy had almost spent itself. The Sierras were made to appear as a distinct range by the subsidence of the Great Basin region.

THE FOSSIL BUTTERFLIES OF FLORISSANT.

BY

SAMUEL H. SCUDDER.

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THE FOSSIL BUTTERFLIES OF FLORISSANT.

By Samuel H. Scudder.

INTRODUCTION.

Having examined more than ten years ago all the butterflies that were known in the European Tertiaries—very few in number—the American forms that have been exhumed at Florissant, in Colorado, in presumably Oligocene beds, have especially interested me. Two of these I owe to the kind communication of friends; the others have been obtained by myself on different occasions. There are, altogether, seven species, more than have been found at any other locality in the world, and only two less than all that are known in the imago state from European deposits. Five of the seven belong to the subfamily *Nymphalinæ*, which claims only one of the European species, *Eugonia atava*. One of the others belongs to the subfamily *Pierinæ*, represented in European Tertiaries by three species. The last represents a nearly extinct type, the subfamily *Libytheinæ*, and is of especial interest. The subfamily *Satyrinæ* and the family *Hesperidæ*, each of them with two representatives in the European tertiaries (the *Satyrinæ* also by a caterpillar presumed to belong here), and the subfamily *Papilioninæ*, with a single member in the beds at Aix, France, are wholly unrepresented, thus far, in American deposits.

The species all belong to extinct genera; those referred to the *Nymphalinæ* are, with one exception, closely allied, and three of them are more nearly related to one another than to any living type. The existing allies of all of them are now to be sought in Central or South America, unless we look for the friends of one among the inhabitants of the warmer parts of the Old World. The Pierid, however, is as close to our ordinary cabbage butterfly (imported from Europe, but with other species of the same genus already existing here) as it is to anything found in warmer climates, while the species belonging to that aberrant group, the *Libytheinæ*, is specially curious, as it resembles least of all the American species of the subfamily, and most of all one that occurs in western Africa. The general aspect, therefore, of the Florissant butterfly fauna is distinctly subtropical and American, while the Tertiary butterfly fauna of Europe is derived in the first place[1] from the East Indies, in the second from subtropical America and in the third from home.

[1] See my Fossil Butterflies, Mem. Am. Assoc., Adv. Sci., I, 1875.

There is a single point in the structure of our Florissant butterflies to which it is worth while to direct attention. In living butterflies, as we ascend the scale of families we find an increasing atrophy of the front legs. In the two lower families, *Hesperidæ* and *Papilionidæ*, they are similar in structure to the other pairs, being normally developed. In the *Lycænidæ* (including in this the subfamilies *Lemoniinæ* and *Lycæninæ*) they are atrophied in the male to a greater or less extent, with the loss of the terminal armature, while still perfect in the female. In the highest family, *Nymphalidæ*, with the single exception of the little group *Libytheinæ*, which agrees with the *Lycænidæ*, they are aborted in both sexes, often to an excessive extent. Now, in *Prolibythea* we have the forelegs of the female preserved, and in *Nymphalites* the foreleg of the male; in both cases they agree in all essential points with what we should expect to find in living forms belonging to the same groups, showing that at the earliest epoch at which butterflies are yet known these peculiar differences, marking the upward progression of forms, were already in existence. We must therefore look for the proofs either of great acceleration in development when butterflies first appeared or of the existence of butterflies at a far earlier period than we yet know them.

CLASSIFIED LIST OF KNOWN FOSSIL BUTTERFLIES.

The following is a classified list of the fossil butterflies of the world, as known up to the present time, with the localities from which they come. Of the European beds, Aix is the oldest and is referred to the Oligocene, Rott to the Lower Miocene, and Radoboj to the Middle Miocene.

Classified list of fossil butterflies.

(Genera still living are italicised.)

Family.	Subfamily.	Tribe.	Genus.	Species.	Locality.
Nymphalidæ	Satyrinæ		Neorinopis	Sepulta (Boisduval)	Aix.
			Lethites	Reynesii Scudder	Aix.
			[Satyrites	Incertus Daudin (larva)	Aix.]
	Nymphalinæ	Vanessidi	*Eugonia*	Atava (Heer)	Radoboj.
			Prodryas	Persephone Scudder.	Florissant.
			Jupiteria	Charon Scudder	Florissant.
			Lithopsyche	Styx Scudder	Florissant.
			Nymphalites	Obscurum Scudder	Florissant.
			Apanthesis	Leuce Scudder	Florissant.
	Libytheinæ		Prolibythea	Vagabunda Scudder	Florissant.
Papilionidæ	Pierinæ	Rhodoceridi	Mylothrites	Pluto (Heer)	Radoboj.
			Coliates	Proserpina Scudder	Aix.
		Pieridi	Stolopsyche	Libytheoides Scudder	Florissant.
			Pontia	Freyeri (Heer)	Radoboj.
	Papilioninæ	Parnassidi	Thaites	Ruminiana (Heer)	Aix.
Hesperidæ		Hesperidi	Thanatites	Vetula (Heyden)	Rott.
		Pamphilidi	Pamphilites	Abdita Scudder	Aix.

THE FOSSIL BUTTERFLIES OF FLORISSANT.

Family NYMPHALIDÆ.

Subfamily NYMPHALINÆ.

Tribe VANESSIDI.

PRODRYAS (πρώ, δρύας).

Prodryas Scudd., Bull. U. S. Geol. Survey Terr., vol. 4, pp. 520–524, (1878).

A stout bodied, strong winged genus. Eyes moderately large. Antennæ remarkably short, scarcely longer than the head and thorax together, the club (Pl. LII, Figs. 2, 3) moderately long, obovate or subfusiform, about twice as stout as the stalk, about five times as long as broad, broadly and regularly rounded at the tip, and composed of eleven or twelve joints of nearly equal length. Palpi (Pl. LII, Fig. 4) extending beyond the front of the head by a little more than the length of the apical joint; the latter about five times as long as broad, equal, cylindrical, broadly rounded at the tip, and uniformly clothed with slender scales; the middle joint appears to be moderately slender and compressed, twice as broad as the apical joint.

The thorax is stout, with the general form of the *Vanessidi,* and particularly of the special group to which *Vanessa*[1] and *Hypanartia* belong. The median ridge of the mesothorax has a minutely impressed line posteriorly; the scutellum is pretty large, lozenge-shaped, slightly broader than long; the metascuta (Pl. LII, Fig. 1) are pretty large, and taper apically at the median line of the thorax to a blunt point. The legs are too imperfectly seen through the wings to give even the length of any part or of the whole of any one with probability. Posterior lobe of patagia about twice as long as its mean breadth, curving outward and tapering regularly and rapidly to a somewhat produced, outer, apical angle.

Fore wings (Pl. LII, Fig. 1) nearly twice as long as broad, unusually triangular, the costal margin almost exactly straight, but bent with a posterior curve at the extremity and slightly convex at the extreme base; the outer margin is also nearly straight on either of its two halves, separated by a slight bend at the extremity of the upper median nervule, the lower half faintly convex; the inner margin is straight, the outer angle only a little rounded.

The costal nervule terminates at the middle of the wing. The first superior subcostal nervule originates shortly before the origin of the first inferior subcostal nervule, and terminates scarcely be-

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[1] That is *Vanessa cardui, atalanta* and allies.

yond the middle of the third quarter of the wing; the second superior and second inferior subcostal nervules originate in the middle of the wing, the latter from the first inferior branch, as far beyond its base as the first superior nervule before it; the former terminates at the middle of the outer half of the costal border; the latter diverges from the first inferior branch so slightly as to be nearly continuous with its basal portion; the third superior branch originates as far beyond the second as the second beyond the first, and the fourth midway between the third and the outer margin; the latter is widely parted rom the main vein, and strikes the costal margin as far beyond the obtuse but distinctly angled apex of the wing as the main branch passes below it. The cell is open. The first median branch originates midway between the base and the final forks, and the latter diverge very slightly at base, leaving a very open and broad subcosto-median interspace.

Hind wings shaped somewhat as in *Hypanartia,* the costal border beyond the great rounded prominence of the extreme base being very gently convex, the outer margin full on the upper half, the upper outer angle broadly rounded; the upper median nervule is developed in the middle of the wing into a long, slender, tapering tail, and the lower half of the wing is strongly crenulate, and especially roundly excised in the lower median interspace and lobed on the lowest median nervule; the lower outer angle is well rounded; the inner margin plainly forms a gutter for the reception of the abdomen.

The costal and precostal veins are very doubtful, being exceedingly obscure on the specimen; but the former apparently arises from the common stem of the costal and subcostal veins at right angles to it shortly beyond the base, and then curves strongly outward subparallel to the costal margin, striking the latter in the middle of its apical half; while the precostal is a simple recurved vein, directed inward and forward at the sharpest point of the costal curve. The subcostal vein is peculiar in that its first branch, originating only a little beyond the costal, approximates so closely to the costal margin as to strike scarcely outside of the upper outer angle of the wing, a place usually reserved for the apex of the costal vein; the subcostal forks again, scarcely more than a quarter of the way from base of its first branch to the margin, the middle branch continuing the curve of the main stem, and the lower branch diverging very gradually from it, and widely distant from the median vein. The main stem of the latter, with its upper branch, forms a gentle sinuous curve, scarcely approaching the subcostal vein (the cell being open), and emits its first branch in the middle of the cell, or scarcely more than half-way from the base to its final divarication. This latter is unusually slight, the middle branch keeping throughout very close to the upper and distant from the lower branch. The submedian strikes the angle of the wing as far from the lower branch as it is

from the middle branch of the median. The internal nervule can not be determined.

The abdomen is full, with the third and fourth joints longest, the whole nearly twice as long, and in the middle fully as broad as the thorax.

PRODRYAS PERSEPHONE.

(Pl. LII, Figs. 1–10.)

Prodryas persephone Scudd., Bull. U. S. Geol. Survey Terr. vol. 4, pp. 524–526 (1878).

The single specimen found is in a wonderful state of preservation, the wings expanded as if in readiness for the cabinet and absolutely perfect, with the exception of the tail of the right hind wing. The thorax and abdomen are perfectly preserved, but indications only of the legs are seen beneath the wings. The head is twisted so as to throw both antennæ upon one side and to exhibit the palpi better than would otherwise be the case. The tongue is doubtless preserved, but the danger of injuring the palpi prevents me from chipping the stone to find it. The antennæ are nearly perfect, but the stalk is covered with a thin film of stone, which will not scale, and thus conceals the joints. The markings of the wings are perfectly preserved, but on the costal area of the hind wings are partially concealed by the overlapping of the fore wings. In almost all the darker parts of the wings the form of the scales even can be determined under the microscope (Pl. LII, Figs. 5–9). This I was unable to do in any of the European fossil butterflies, although in some of them the points where they were inserted could be seen; nor have I been able to satisfactorily determine their form on any of the other species here described.

The wings are rather dark brown, deepening in tint on the front wings toward the extreme base and along the immediate costal edge, ornamented with pale markings, which were probably bright colored in life. Fore wings with a mesial, transverse, slightly arcuate band, extending across the wing at right angles to the costal border, just failing to reach either margin, divided by every nervule, its inner margin continuous and nearly straight, its outer strongly crenulate, being gently convex in the discoidal cell (more below than above), strongly convex in the lower median and submedio-internal interspaces, and strongly sinuous in the medio-submedian interspace; its upper extremity is before the middle of the wing, and incloses in its middle the base of the first superior subcostal nervule; its outer border is bent inward below the cell, exactly to the last divarication of the median nervure, and it reaches the anal area of the wing two-thirds the distance from the base. A row of five unequal pale spots crosses the wing in a straight line, extending from the lower outer angle to

the costal margin at two-thirds the distance from the base; four of these are approximated in the subcostal interspaces; the fifth and largest is in the middle of the upper median interspace, but nearer the middle than the upper median nervule; it is broadly ovate and obliquely placed, subparallel to the mesial band, its broader extremity above; the lower of the subcostal spots, before the middle of the lowest subcostal interspace, is obovate, still more oblique, pointing toward the upper of the subcosto-median spots to be mentioned, and only a little smaller than the median spot. The three spots above this are equal, about half as large as the latter, twice as long as broad, rounded, subquadrate, each occupying nearly the breadth of the subcostal interspaces next succeeding; the upper two appear as a single spot, being scarcely divided by the intervening third superior subcostal nervule. Still nearer the outer margin of the wing, and parallel to the row of spots just mentioned, are two subequal, rounded, obovate spots, slightly broader than long, the upper a little the larger, together occupying the entire breadth of the subcosto-median interspace, removed by less than twice their width from the row of spots previously mentioned; the fringe of the wing appears to be slightly darker than the ground-color.

Hind wings with a very large pale spot occupying the entire upper outer angle of the wing, reaching from the outer margin nearly halfway to the base, and from the costal margin to the upper median nervule; its basal margin is convex in the subcosto-median interspace, following what would perhaps naturally be the outer limits of the cell, while on either side of the lowest subcostal nervule the spot is separated from the outer margin of the wing by a narrow dark edging. On the irregular border which faces the median nervure, this pale spot emits three long, more or less sinuous tongues of pale color; one a very narrow, nearly straight stripe or line along the margin itself, which extends only to the elongated upper median nervule, the breadth of the spot being less toward the margin than in the middle of the wing; a second, subparallel to the outer border, and therefore arcuate, as well as slightly sinuous, subequal, more or less broken into transverse spots, extending to the inner margin, and distant beyond the middle median nervule about half an interspace's width from the outer margin; beyond the submedian it is very faint, and above it the spot is broader; the third, slightly narrower, subparallel to the second, but running more nearly at right angles to the nervules, extends in a slightly sinuous course across the median interspaces only, tapering apically. In addition to these markings, there is a series of submarginal pale dots in the lower half of the wing, one in the narrow (upper median) and two in each of the broader interspaces, besides a larger roundish or subtransverse dark spot, deepening centrally in color, in the medio-submedian interspace, between the submarginal pale dots and the middle tongue

of the large pale spot, which here tend to inclose the dark spot in an annular pale ring, and give it the appearance of a rather obscure ocellus. Above the tail, the fringe appears to be concolorous with the pale ground; below it, darker than the adjoining dark ground-color.

The scales on the outer half of the fore wing (Pl. LII, Figs. 5–9) are two or three times as long as broad, with straight parallel sides, a well-rounded base, and a deeply combed, often strongly arcuate apex, consisting of from three to five, usually four, entirely similar, equidistant, tapering, finely pointed teeth, of equal length, or the middle ones slightly larger, the outer ones at the edges of the scale, all nearly a third as long as the scale itself.

Length of body, 22^{mm}; of palpi, 2.4^{mm}; last joint of same, 1.3^{mm}; of antennæ, 10.5^{mm}; of club of same, 2.5^{mm}; breadth of latter, 0.85^{mm}; length of thorax, 6.5^{mm}; its breadth, 5.5^{mm}; expanse of wings, 54^{mm}; length of front wing, 24.5^{mm}; its outer margin, 18^{mm}; its inner margin, 15^{mm}; breadth of wing, 14.5^{mm}; length of hind wing, excluding tail, 18^{mm}; additional length of tail, 3.25^{mm}; breadth of latter at base, 1^{mm}; in the middle, 0.55^{mm}; greatest breadth of hind wing, 16.75^{mm}; length of abdomen, 13^{mm}; breadth of same, 5^{mm}.

Florissant, one specimen, No. 394.

This is the first butterfly fossil found in America, and as only nine species are known in the imago state from the well-worked Teritary strata of Europe, it may properly be esteemed an especial rarity. Besides this it has a double value: first, in that it is far more perfect than any of the European specimens (nearly all of which I have seen) or than any other of the species here described; and, second, in presenting, as none of the others do to any conspicuous degree, a marked divergence from living types, combined with some characters of an inferior organization. When first received, the tails of the hind wings and the tips of the antennæ were hidden by flakes of stone, and it was taken, both by myself and by every entomologist to whom I showed it, to be a Hesperian, the lowest family of butterflies. The neuration, however, which, although mostly very obscure, can be determined with certainty, shows it to be a Nymphalid, the highest family, with which the structure of the antennæ and palpi and the outline of the hind wings, now entirely uncovered, perfectly agree. The first inference was drawn principally from the robustness of the body and the form, proportions, and markings of the fore wings. The latter are unusually long for a Nymphalid of this type, have a remarkably straight costa, an outer border bent at the middle instead of far above it, and are possessed of a nearly transverse, median, light-colored belt on a dark ground, a subapical row of small spots depending from the costa, a spot in continuity with them in the upper median interspace, and beyond them, parallel to the outer border, in the costo-subcostal interspace, a pair of minute spots —

all characters perfectly consonant with Hesperian affinities; never combined, and each very rare in the *Nymphalidæ.* It is not a little strange, however, that while the form and markings of the fore wings are hesperidiform, those of the hind wings are decidedly nymphalidiform. That the exact opposite should be a far more probable occurrence follows as an assumption, from the fact that, as a general rule, the front wings only of the lower *Lepidoptera* are ornamented, and that therefore the ornamentation of the hind wings is a more recent development. The somewhat variegated markings of the hind wings are indeed similar to what we find in certain *Hesperidæ*, such as *Pythonides*, but they are far more common in *Nymphalidæ*, while the wing contour is of a high nymphalideous type, quite above anything we ever find in *Hesperidæ.*

I am at a loss to suggest any really plausible explanation of the mode of development through which the hind wing should have attained an ornamentation consistent with its organization, while the ornamentation of the fore wings, whose structural framework has kept pace with that of the hind wings, has not advanced a single step beyond a type common to the lowest family of butterflies. It may, however, be suggested as a mere speculation that the position in which the wings of many *Hesperidæ* are held in repose (the front wings oblique or suberect, while the hind wings are horizontal, and therefore more fully exposed to view) might be productive of such a result. In this case we should anticipate further indications of such a feature, at least in fossil forms. We are acquainted with the upper surface markings of both pairs of wings in extinct butterflies only in *Lithopsyche styx*, *Neorinopis sepulta* (Boisd.) and *Thaites ruminiana* Heer. It had escaped notice in my original study of the two last[1] that when they are compared with living types, indications appear of precisely the same nature, although by no means so conspicuous. The rude patches of color that mark the discoidal area of the front wings of *N. sepulta*, and the repetition of almost similar, unbroken, transverse bars on the same portion of the front wings of *T. ruminiana*, when compared with these parts in their nearest living allies, are clearly indications of an inferior as well as an earlier type, while no such contrast is presented in the delicate shading and more complicated pattern of the hind wings. I notice nothing of the sort in *Lithopsyche.* But, again, a partial comparison may be made with the markings of the front wing alone, and in the other species of described fossil butterflies there is not one, with the possible exceptions of *Apanthesis leuce*[2] Scudd. and *Eugonia atava*[3]

[1] Mem Am. Assoc. Adv. Sci., I, 1875.

[2] None of the living allies of *Apanthesis* have anything like the simple markings of this fossil.

[3] The remnant of this insect's front wing is certainly simpler in markings than the upper surface of allied living *Eugonias*, but it may represent an inferior surface, in which case there is no special difference.

(Heer), in which the markings may be looked upon as less highly developed than in the living types.

Instances could, of course, be easily given from among living types in which the ornamentation of the upper surface is less variegated in the fore wings than in the hind pair, but it might readily be doubted whether this should be looked upon as having any direct bearing upon this subject; yet, even if none could be cited, it might fairly be urged that the lapse of time since the Florissant beds were deposited is amply sufficient for the loss of any such indication of hesperidiform affinities in a group of insects so pliable in ornamentation as butterflies are shown to be by the mere facts of mimicry.

Prodryas shows further peculiarities when compared with its nearest living allies. In the tropical American genus *Hypanartia*, which seems to be its nearest neighbor, as in all those closely allied to it at the present day, the costal margin beyond the base is uniformly arched throughout; and the outer margin, angulated in the upper half of the wing, is roundly excised below it, giving the European allies of these butterflies the common name of "angle wings." They are insects of strong and rapid flight, capable of the most abrupt and unanticipated movements, making them very difficult of capture on the wing. The straight, strong costa and more elongated wing of *Prodryas*, on the other hand, with its nearly uniform, straight outer border, combined with the robustness of the body, indicate great strength of wing and a rapid direct flight, as in the *Hesperidæ*, but not the power of sudden turning.

In *Hypanartia* and its immediate allies, the cell of the front wing is closed, although by a feeble vein, and the superior subcostal nervules take their rise at more or less irregular distances apart, and run long distances crowded side by side; while in *Prodryas* the cell is open, and the subcostal nervules are much shorter and very uniform in their distribution; the inferior subcostal nervules also originate in *Prodryas* in a much simpler fashion, indicating that its ancestors never had the cell closed, although a foreshadowing of the closure may be seen in a row of special scales (or a line of color) at the supposititious termination of the cell. That this can hardly indicate a true vein appears from the fact that there is not the slightest tendency of the opposing veins to approach each other at its extremities, a tendency which it would seem should naturally precede the formation of a vein; the second inferior subcostal nervule takes its rise from the first in just about the same manner as the second superior nervule originates from the main stem, neither its basal portion nor that of the first inferior nervule showing any noticeable tendency to bend abruptly and to help form the termination of the cell, as now appears in all *Vanessidi* to a greater or less extent, and which, in some open-celled genera, seems to indicate the loss of a transverse discoidal veinlet after a previous possession. The presence of a

transversely disposed pair of spots in the costo-subcostal interspace also indicates the probability that this interspace had hitherto never been narrower nor bridged by a vein.

In the hind wings there are two features of importance besides the unusual openness of the cell, which is scarcely narrowed apically. The first is the course of the first subcostal veinlet, which originates far toward the base of the wing, and terminates where the costal nervure is sure to end in nearly all *Vanessidi,*[1] at the upper outer angle of the wing. This necessitates a shortening of the costal nervure. I do not know of a single instance of such a feature among the members of this group of *Nymphalidæ*, but it is an almost persistent character in the *Pierinæ*, and very common in the *Satyrinæ*. The other point is the extreme narrowness of the upper as compared with the lower median interspace, the former being scarcely more than half as broad as the latter, owing to the slight divergence and continual proximity of the outer branches of the median vein. The only other feature in which it differs unusually from its allies is in the brevity of the antennæ.

JUPITERIA, gen. nov.

Allied to *Prodryas* and *Junonia*. Fore wings (Pl. LII, Fig. 14) triangular, with a somewhat pointed tip, the costal margin gently and regularly convex, the outer margin entire and straight, and the inner margin straight. Hind wings subcircular, longer than broad, the costal border slightly concave, much as in *Eunica*, the outer margin crenulate, perhaps prolonged into a tail near the lower median nervule, the inner border not very full.

Costal vein of fore wings terminating about the middle of the border; subcostal vein terminating some distance below the tip of the wing, bending downward from its outer branch; first superior nervule thrown off long before the first inferior nervule; second, third, and fourth at equal and wide distances apart beyond the first inferior, the fourth about midway between the origin of the latter and the tip of the wing; first inferior nervule parting rather widely and regularly from the main branch beyond the origin of the middle median nervule; second inferior branch arising from the first at a little distance from its base and at once separated widely from and running parallel to it; cell apparently open. Last median branch bent at base as if to connect with a discoidal nervule and running nearer the adjoining subcostal nervule than the neighboring median nervule. Submedian nervure near the inner margin.

Costal vein of hind wing running, as in *Eunica*, very close to the margin. Subcostal branches arising at a moderate distance apart, the second at a considerable distance before the first median branch.

[1] In *Polygonia* and some of its immediate allies the upper outer angle of the hind wing is curiously excised, throwing the costal nervure back some distance.

Median nervules equally and widely distant near their base, the last curving as if to close the cell, opposite a point just before the middle of the lower subcostal nervule.

This genus is perhaps nearer to *Prodryas* than to any existing type, though it is still nearer to *Lithopsyche*. From the former it differs in the basal breadth of the lower two subcostal and last median interspaces, in the approximation of the adjoining subcostal and median nervules and the approximation of the submedian nervure to the margin of the front wing; in the hind wing it differs greatly both in form and the course of the nervures. From *Lithopsyche* it differs in the narrower fore wing, the approximation of the subcostal nervure to the costal border, the equal separation of the bases of the superior sub-costal nervules, the later origin of the inferior subcostal nervule as compared to the median, the wider basal divergence of the first inferior subcostal nervule, the open and narrower cell, and the straight inner margin. The hind wing further differs in its greater comparative length, the excised costal margin and close approximation to it of the costal nervure, the earlier and less distant branching of the subcostal nervules, all of which arise before the first branch of the median, the possible caudal appendage at the inner angle of the wing and its narrower inner lobe.

Concerning its relations to living types, the hind wing, excepting the possible tail, resembles remarkably, both in form and neuration, that of *Eunica*, a genus of the neighboring tribe of *Nymphalidi*, but the branching of the middle veins of this wing is much later in the fossil form; the fore wing, on the other hand, is very different, both in the open and much longer cell, and in the origin of the second superior subcostal nervule, in which it agrees better with most of the *Vanessidi*. The neuration of the hind wing, excepting of the costal vein, is very close to that of *Junonia*, in which also there is a slight extension of the lower median nervule and the submedian nervure; but in the front wing we have here considerable differences in the longer cell, due to the later origin of the inferior subcostal nervules, the second of which arises at some distance beyond the first, and not at the point of its origin; while, further, the relation of the second superior subcostal nervule is very different from what it is in the fossil species, being approximated to the first and arising before the end of the shortened cell, as in *Eunica*. The straight outer margin of the front wing, the excised costal border, and the normal extension of the first median nervule of the hind wing separate it at once from *Hypanartia*, from which in its neuration it is not remotely distant; for instance, it has a strong resemblance in the length and general relation of the cell of the front wing, though not in its closure; but here, as elsewhere, the relations of the second superior subcostal nervule are different. Indeed, it would appear as if *Jupiteria* and *Prodryas* belonged to a peculiar section of *Vanessidi*

in which the superior subcostal nervules of the fore wing arose at subequidistant intervals, the second beyond the cell; and that *Lithopsyche*, though agreeing better with the ordinary types now existing, still showed in the origin of its second superior subcostal nervule, opposite the base of the first inferior nervule of the same vein, a tendency in the same direction.

JUPITERIA CHARON, sp. nov.

(Pl. LII, Figs. 14, 15.)

Body moderately stout. Fore wings short, triangular, somewhat less than twice as long as broad, the costal margin gently and regularly convex (the tip probably rounded), outer margin nearly straight and uniform, inner margin very gently convex. Cell about four-ninths the length of the wing, open.

Costal nervure terminating a little before the middle of the wing. Subcostal nervure terminating by its apical nervure at the tip of the wing, running almost exactly parallel to the costal margin; the first superior subcostal nervule originates just before the end of the first third of the wing, a little further out than the first median nervule, and terminates at the end of the third fifth of the wing; the second superior subcostal nervule originates opposite the end of the cell, just before the tip of the costal nervure, and terminates just before the end of the fourth fifth of the wing; the third superior subcostal nervule originates just below the tip of the first superior subcostal nervule and terminates about midway between the tip of the preceding and the tip of the wing; the fourth superior subcostal nervule continues the course of the subcostal nervure, while the nervure itself bends downward, parting rather widely from the nervule and running parallel to the nervules below; the first inferior subcostal nervule originates slightly nearer the base of the first than of the second superior nervule, or at the end of the second fifth of the wing; the second inferior subcostal nervule originates from the first a short distance from its origin and exactly opposite the base of the second superior nervule, by a curving base which is very feeble and scarcely perceptible, and then runs subparallel to the first inferior subcostal nervule and slightly nearer it than the nearest median nervule. The median nervure diverges pretty widely from the subcostal, and its first nervule nearly continues its course, bending widely from it at about the end of the third fifth of the cell; the second and third nervures part from it at equal distances apart, the nervure running parallel to the subcostal nervure between the first and second, and bending somewhat further upwards between the second and third nervules. No cross vein connecting this last with the subcostal nervules. The cell is open. The submedian is nearly straight and widely separated from the first median nervule.

Hind wings of a rounded form, with the lower half of the outer margin broken in the single specimen seen, so that its form in that region can not be determined; but the length of the first median nervule leads to the conclusion that it bore a tail, probably like that seen in *Colobura*, and only slightly longer than the dentate prominence of the last median nervule. The costal margin has a small shoulder, beyond which it is very slightly concave. The upper half of the outer margin is well rounded and crenulate between the nervules. The inner margin is very obscure, but appears to be broadly convex.

The costal and subcostal nervures spring from the same point, the former being directed forward in a nearly straight line until the precostal is reached; this is short and only slightly curved, directed toward the angle of the costal shoulder; beyond the precostal nervure the costal runs in a nearly straight line, gradually approaching the margin, which it almost reaches at the middle of the margin, and then runs in very close proximity to it to the extremity of the margin. The subcostal nervure runs parallel to the costal margin as far as the origin of its first nervule, which, nearly continuing its course, passes in a broad sweep to the margin; the vein itself then bends downward parallel to the median nervure, running thus nearly as far as its undivided stem, when the second and third nervules arise and pass with a sweep similar to that of the first nervule but diverging more and more from it. The median nervure runs in a straight line nearly to the middle and to only a little below the center of the wing, where the first nervule is thrown off; this bends a little downward and runs in a straight course to the margin; the vein then turns upward so as to be parallel to the base of the subcostal nervure, and at equal and wide intervals emits the other two nervules, which are almost equally straight; the point, however, where the third may be said to part from the main nervure (or the basal portion itself of the nervule) is very strongly curved, and approaches the lower subcostal nervule, with which it is in no way connected, the cell being open. Considering this point the end of the cell, the latter is considerably more than half as long as the wing. The submedian nervure is straight, runs widely distant from the median nervure and its lowest branch, and terminates at the lower outer angle of the wing. The internal nervure is also straight and ends slightly before the middle of the inner border.

Little can be said of the markings of the wings, because most of them are obscure and are in the region where the wings overlap, making it difficult to say whether they belong to the fore or hind wing. Judging from their position relative to the nervules, it would, however, appear more probable that they belong to the hind wing, although it must remain very doubtful, the more so as the portion of the hind wing not covered by the front wing presents no appearance of ornamentation, which it would be likely to have possessed,

though not necessarily, did the ornamentation seen belong to the hind wing. If the markings do belong to the hind wing it affords another example of the greater ornamentation of the hind than of the front wing. Possibly the markings of both wings are commingled in the lights and shades which appear. The general ornamentation may be stated as follows: The wings were of a dark color, with decided light colored small bars depending from the costal margin just beyond the middle, while the outer half of one or both wings was mottled with fainter, light colored, vaguely bounded, quadrate spots, collected to a certain extent into two or three rather distant transverse bands parallel to each other and to the outer margin. The only markings which can be definitely referred to one or the other wing are the costal spots. Those in the fore wing consist of a quadrate spot at about the end of the third fifth of the wing, its outer margin at the tip of the first superior subcostal nervule, falling very nearly (perhaps quite) to the first inferior subcostal nervule, and therefore nearly twice as deep as long; and a fainter, much smaller spot at the tip of the costal nervure, which is nearly circular. On the hind wing there are also two such spots, but they are equal and similar, excepting that the outer is the fainter, and both are smaller than the larger spot of the fore wing; both reach the upper subcostal nervule, and are about half as long as deep; the inner is situated with its interior edge at the middle of the costal margin, the outer separated from the inner by its own width.

No appendages of any importance can be seen. Only a few basal joints of the antennæ are preserved, directed forward, with traces of the palpi in a somewhat confused condition, and slight projections next the base of the front wings, which are doubtless a part of some of the legs, perhaps the front pair. The abdomen reaches to a point rather more than midway between the tip of the internal and that of the submedian nervures, and is full and well rounded, rather indicating a female.

Length of body, 19^{mm}; of fragment of fore wing, 24^{mm}; probable entire length of same, 27^{mm}; breadth of same, 15^{mm}; distance from base of wing to tip of cell, 12^{mm}; width of cell, 3.5^{mm}; distance from base of hind wing to tip of lowest subcostal nervule, 20^{mm}; same to tip of lowest median nervule, as far as preserved, 20^{mm}; breadth of hind wing, 17^{mm}; probable expanse of wings, 54^{mm}.

A single specimen from Florissant, Colo., in the collection of Mr. R. D. Lacoe, of Pittston, Pa., bearing the number 2,100, presents a view of the upper surface.

LITHOPSYCHE (λίθος, ψυχή), gen. nov.

Allied to *Jupiteria* and *Hypanartia.* Fore wings (Pl. LII, Fig. 17) triangular, very broad, the costal margin uniformly convex, the outer margin straight, and the inner full toward the base. Hind

wings regular, rounded, with no upper angle, and a broadly guttered inner margin, the outer margin entire.

Costal vein of fore wings terminating before the middle of the margin. Cell about half as long as the wing, closed by a straight, strong vein. Subcostal nervure distant from the margin; the first three superior nervules emitted not far apart, long before the fourth, the first a little before the second at the origin of the first inferior nervule; this last originates about opposite the middle median nervule and does not part widely from the main vein for some distance; second inferior nervule arises close to base of first, but at once becomes widely separated from and then parallel to it, being angulate at tip of cell; last median much approximated to the lowest subcostal nervule, running considerably toward it, even beyond the tip of the cell; discoidal striking the median nervure as far beyond origin of second as the second is from the first median nervule. Submedian nervure near inner margin.

Subcostal branches of hind wings arising at a considerable distance apart, the last opposite a point midway between first and second median branches; median branches equally and widely distant next base, the last curved abruptly opposite a point just before the middle of the lowest subcostal nervule.

This genus is nearer *Jupiteria* than any living genus. It differs from it, however, in several prominent points. The fore wing is far broader with a less pointed apex and a full inner border; the cell of the same wing is distinctly closed; the subcostal nervure is distant from the margin, and its first three superior veins are clustered at a distance from the last; the second arises opposite instead of beyond the inferior nervules, the latter are also thrown inward as related to the median nervules, and the upper of them runs at first close to instead of parting from the main vein. In the hind wing the circular form is very different, with its full costal and inner margin and its uniform outer border; the costal vein does not hug the margin, while the subcostal branches, instead of arising before the median are nearly opposite them. It is still further removed from *Prodryas*, from which it differs in nearly all the points in which the latter differs from *Jupiteria* as noted under that genus, even in the differences mentioned as to the origin of the superior subcostal nervules of the fore wing.

Compared with existing types, it appears to agree far better with *Hypanartia* than with any other genus, but differs from it quite as widely as it does from existing neighboring genera. In the (most probably) straight and entire outer margin of the fore wing, its full almost lobed inner margin, and the exceedingly uniform rounded contour of the hind wing it differs strikingly from it. In the neuration, also, there are important points of distinction; the costal nervure of the fore wing is much longer in *Hypanartia*, the subcostal nerv-

ure is not so distant from the margin, and the second superior nervule is much more closely approximated to the first and distant from the third, arising before the inferior nervules; the cell is closed by a vein which is continuous with and does not form a right angle with the base of the second superior subcostal nervule, and yet strikes the median nearer the middle branch than in *Lithopsyche*. In the hind wing of *Hypanartia* the subcostal branches originate much closer together and nearer to the base as compared with the median nervules, while the last median nervule is not so strongly bent and widely distant from the middle median nervule as in *Lithopsyche*.

In the markings of *Lithopsyche*, which are apparently those of the upper surface, I can find nothing whatever to compare with any existing type remotely connected with the fossil. The most conspicuous features of these markings, besides the costal and discoidal spots of the fore wing found in so many butterflies, are a pair of spots, one at the base of the upper median, the other ocellate, at the extremity of the lower median interspace of the fore wing; these are repeated in exactly similar relations in the subcostal interspaces of the hind wings, and are therefore undoubtedly translated correctly from the confusion of the overlapping wings (Pl. LII, Fig. 11). Such a combination with a mottled median area on the hind wings is altogether unique, so far as I can discover, among *Nymphalinæ*. The only markings found on the fore wings not seen on the hind pair are the costal spots; while the only ones on the hind wings not repeated, in some sense, on the fore wings, are the mottlings of the median area, which, though much more extensive and complicated than that of the fore wings, does not add materially to the points urged in my account of *Prodryas*, concerning the relative ornamentation of the front and hind wings.

LITHOPSYCHE STYX, sp. nov.

(Pl. LII, Figs. 11, 16, 17.)

The wings, and those only of one side, are preserved. The hind wing is nearly perfect, but the apex of the fore wing is gone. The character of the neuration of this wing, however, coupled with the course of the margins of the wing, enables us to restore the form and even the missing veins with reasonable certitude, as given in Fig. 17. Assuming this restoration to be correct, the fore wing is half as long again as broad, triangular in shape, the costal margin regularly and gently convex (the tip bent but rounded), the outer margin nearly straight and entire, the inner margin nearly straight excepting for a broadly convex portion on the basal two-thirds. The costal nervure is short, terminating before the tip of the cell, or only a little beyond the tip of the second fifth of the margin.

The subcostal nervure is almost exactly parallel to the margin throughout; the first superior subcostal nervule originates just before

the end of the second fifth of the wing, and running parallel to but very distant from the costal nervure, terminates at the end of the second third of the wing; the second superior subcostal nervule originates just beyond the first, beneath the tip of the costal nervure, and terminates at a scarcely greater distance beyond the first than it had at starting; the third superior subcostal nervule originates a little beyond the middle of the wing, and runs parallel to the second; its apex is in the broken part of the wing, but is probably either not a great distance before the tip or midway between it and the tip of the preceding; the fourth superior subcostal nervule is wholly in the broken part of the wing, but from the wide divergence of the first inferior subcostal nervule is probably much as represented in the figure, originating about midway between the base of the third superior nervule and the outer border, and terminating at the tip of the wing; the first inferior subcostal nervule springs from the main vein directly opposite the base of the second superior nervule, parts from the main vein at first gently, afterwards rapidly, and must terminate near the middle of the upper half of the outer margin; the second superior subcostal nervule springs from the first inferior nervule almost at its origin, is deflected in a straight course toward the middle of the outer margin of the wing until it meets the vein closing the cell, with which it forms slightly more than a right angle, and where it is nearly as distant from the subcostal nervure as that is from the costal margin; it then turns abruptly and follows a curve like the first superior subcostal nervule, but slightly divergent from it. The median nervure is widely divergent from the subcostal nervure until it emits its first branch, which is straight, bent downward from the main nervure at a very broad angle, and originates at the end of the second third of the cell; beyond this branch the median nervure passes with a couple of nearly equal broad curves, the first parallel to the subcostal nervure, the second turned a little upward to meet the vein closing the cell, which is straight and a little shorter than the basal portion of the second inferior subcostal nervule; the second median nervule is straight, and so is the third beyond the base, which is strongly curved, continuing the course of the extremity of the main vein so as to bring the basal part of the third median nervule as near to the second inferior subcostal nervule as the latter is to the first inferior nervule, and giving to the whole median nervule a course almost exactly parallel to the nearer subcostal nervule. The submedian nervure is straight, widely distant from the median nervure and its first branch, and closely approximated to the inner margin, at the subangular termination of which it ends. The closed cell is about two-fifths the length of the wing and two and a half times longer than broad.

The hind wing is well rounded, with entire margin, a little longer than broad, the costal passing insensibly into the outer margin, and

the lower outer angle probably almost equally rounded, the edge of the wing, as preserved, being probably folded at this point. The base of the inner margin is broadly lobate, indicating that it formed a gutter for the inclosure of the abdomen. The costal margin is not very abruptly curved at the base, and the precostal nervure can not be made out; the former is tolerably distant from the margin.

The subcostal nervure and its first branch run in one scarcely curved continuous line parallel to the larger part of the costal nervure; at the origin of this branch, which is two-sevenths the distance from the base, the costal nervure turns abruptly downwards parallel to the median nervure and at a considerable distance on or opposite a point midway between the first two branches of the median forks, the middle branch passing in a very gentle curve, the lower by a gently sinuous course to the outer margin. The median nervure is at first directed toward the tip of its middle branch, and opposite a point midway between the bases of the first two subcostal nervules emits its first straight branch scarcely bent downward from the course of the previous portion of the main vein; the latter is then bent gently upward, this portion of its course being equal in length to the similar part of the subcostal vein, and then emits its middle straight branch and its outer branch, both subparallel to the first branch, but the latter roundly bent beyond the base and so approximated somewhat closely to the lower subcostal nervule at a point a little before the middle of the latter, with which, however, it is not at all connected, the cell being open. The submedian nervure is gently curved and terminates at the outer angle. The internal nervure terminates at the middle of the inner border.

Although the wings are almost completely overlapped (Figs. 11, 16), the markings of the two wings can be separated with considerable certainty by referring them to the interspaces of one or the other of them. On this basis they may be described as follows: The ground color of both wings was dark with lighter markings, which in the fore wings were distributed in moderate sized patches mostly in the middle of the upper half of the wing; on the hind wings clustered into irregular mottling, mostly in the lower half of the outer portion of the wing. On the fore wings the lighter patches consisted of two spots depending from the costal margin, one broad, opposite the middle of the cell and reaching only so far as it, with the exception of a slight middle extension into the top of the cell; the other only half as broad, half way between the first and the tip of the wing and reaching to the first inferior subcostal nervule; between these was also a faint cloud; a still narrower patch traversed the cell near its extremity; and near the base of the upper median interspace and filling it at that point was a large irregularly quadrate spot, infringing slightly on the lower median interspace at one corner, not cross ing the interspace regularly, but having its sides placed more in re-

lation to the costal margin; in addition, in the outer half of the lower median interspace, is an obscure, irregular, rounded spot as large as the interspace, and perhaps obscurely ocellate.

On the hind wings few of the markings appear very pronounced; the most so are those situated above the cell. These are a round spot in the upper subcostal interspace, just beyond the base of the middle nervule and scarcely filling the width of the interspace; and an ocellus, perhaps imperfect above and with a large pupil, filling the lower subcostal interspace just before the margin. There is also a small roundish spot in the cell below the base of the middle subcostal nervule; another distinct and round or pyriform spot crosses the base of the upper median interspace. The rest of the markings of the wing are in the form of a nearly equal mottling of dark and light shades formed by irregular narrow light bars transverse to the interspaces, on a dark ground, which fill the outer third or quarter of the upper median, the outer two-thirds of the lower median, and the outer third of the medio-submedian interspace.

Length of fragment of fore wing, 22^{mm}; its probable entire length, 27^{mm}; breadth of same, 15^{mm}; length of cell, 13^{mm}; breadth of same, 4.25^{mm}; length of hind wing, 20^{mm}; breadth of same as preserved, 18^{mm}; probable actual breadth, 19.5^{mm}.

The single specimen was obtained some years ago at Florissant, Colo., by Mr. Israel C. Russell, now of the U. S. Geological Survey, who has allowed me to study it.

NYMPHALITES OBSCURUM, gen. et sp. nov.

(Pl. LIII, Figs. 10–13.)

We apply this name to the most vaguely and imperfectly preserved of all our fossil butterflies, of which enough remains in sufficient preservation to indicate the family to which it belongs, and to some extent its closer affinities. It is preserved with spread wings, of which the borders are preserved only in the costal region, and the position of a few veins can be determined, without revealing in the least the character of the discoidal cell of the front wings. One of the antennæ, and particularly its club, is tolerably well preserved (Fig. 11), as is also a bit of the tongue; while one of the fore legs (Figs. 12, 13) is sufficiently clear to make out the joints, and to show by its aborted character that the butterfly must belong in the *Nymphalidæ*. That it was a male is indicated by the preservation of a part of the upper organ of the abdominal appendages. It is possible that a thorough scrutiny of an extended series of this family would enable one to decide, by correlating the structure of the antennæ and fore legs, in what neighborhood it should fall. But as this is not at present in my power, I have preferred to designate it provisionally by a generic name indicating merely its family relation, as is not

seldom required in the study of fossil insects. Nearly all the characters which will be given below are of a generic nature.

The body is very stout, while the head is comparatively small, and the tongue slender. The wings are very ample, with a pretty strongly arched costa to the fore pair, especially toward the base; none of the veins are swollen at the base, and nothing characteristic appears except that the ordinary form of superior apical branching seen in the subcostal vein of the fore wings of *Nymphalinæ* appears also here. To judge from this forking the wing is apparently broken off just before its apex, and is about one and three-quarters the length of the body. The antennæ are short, being a little less than half as long as the wings, very slender, with a very gradually incrassated club (Fig. 11), which is nowhere double the thickness of the very slender stem, occupies nearly the apical fourth of the antennæ, and is composed of about fourteen or fifteen joints, which increase mostly in size in the basal half of the club, then scarcely increase, while the decrease is entirely confined to the last two joints and mostly to the ultimate, the extremity being well rounded and not at all produced; the joints of the whole club are of nearly equal length, and the largest about twice as broad as long. The fore leg (Fig. 12) is somewhat less than half as long as the antenna, tolerably stout, the tibia nearly as long as the femur, the tarsus somewhat shorter than the tibia, showing four joints, of which the first is somewhat shorter than the rest combined, and the last (Fig. 13) is armed with slender short spines. The last segment of the abdomen shows in the middle what appear to be the curving sides of the tapering hook of the upper organ, of the ordinary form.

This is the first instance in which the atrophy of the fore legs, so well known to be common to both sexes of recent *Nymphalidæ*, has been shown to occur in a fossil form. That it should be less pronounced than in recent times is not surprising, and it is fortunate that we have independent, though not absolute, proof that the individual was a male. The amount of atrophy in size is about equal to what is found in the male *Lycænidæ* to-day, or possibly a little more. The femur is much less than half the size of the middle femur; the tibia, on the contrary, though not half so long as the middle tibia, is shorter than it, while the tarsus bears the proportion to its own tibia common to recent *Nymphalidæ*, and the armature at tip is reduced to a few spines.

The stout body, ample wings, and the remarkably short and very slender antennæ, with their slight and gradually incrassated club, are found combined in no genus of butterflies found in temperate North America. *Timetes* and the genera allied to it (which are really Central American types, but invade our southern borders) perhaps approach nearest to it, and especially *Cymatogramma*, a Central American type; but all of these have much slenderer bodies than

are indicated here, and, so far as I have been able to examine them, have far slenderer fore legs. On the whole, however, I am inclined to place the fossil form in this vicinity, until at least further light can be obtained from additional specimens.

Expanse of wings as preserved, 55.5^{mm}; probable expanse of wings, 63^{mm}; length of body, 18^{mm}; of antennæ, 13^{mm}; of fore tibia and tarsus, 4^{mm}; of fore tibia, 2.2^{mm}; of middle tibia, 4.5^{mm}.

Florissant, one specimen, No. 7,768.

APANTHESIS (ἀπανθέω), gen. nov.

Allied to *Anelia* Hübn. (*Clothilda* Blanch.) and *Cirrochroa* Doubl. Front wing only known. It is subtriangular (Pl. LII, Fig. 13), and, excepting the strongly sinuate inner margin, of very simple form, the costal and outer margins being gently (the latter very gently) convex, and rather feebly crenulate between the nervules; there is hardly any basal curve to the costa. The costal nervure is crowded close to the subcostal and terminates nearly opposite the end of the cell or beyond the middle of the margin. The subcostal is generally parallel to the costal margin throughout its course, its first and second superior nervules originating near together before the end of the cell, the second as far before it as it is after the first, the third and fourth superior far apart and far from the basal offshoots, dividing nearly equally the distance beyond the cell, the fourth terminating at the tip of the wing; the first inferior subcostal nervule parts at the tip of the cell at a very slight angle from the nervure, continuing with great regularity to the outer margin, the curve of the subcostal nervure immediately before its origin; the second inferior subcostal nervule is very obscure at its origin, but apparently arises so close to the base of the first inferior nervule that there is practically no so-called upper disco-cellular nervule; the middle one is a little shorter than the lower and with it, also very obscure, lies in a nearly straight line, striking the median nervure nearly as far beyond the origin of the middle nervule as that beyond the basal. The discal cell is thus half as long as the wing, subquadrate in its outer, cuneiform in its basal half, and about three times as long as broad. The middle median nervule arises opposite the second superior subcostal nervule. The submedian vein is remarkably straight, considering the great sinuosity of the inner margin, and on the basal half of its course is nearly as distant from it as the nervules are from each other on the outer margin. Internal nervure wanting.

The markings consist of a uniform dark ground with a narrow banded series of pale sublunular spots, almost exactly parallel to the outer margin and much nearer it than the apex of the cell.

Without the other parts of the body to guide us, it is somewhat difficult, and perhaps a little hazardous, to venture any decided opinion as to the precise relationship of this fossil. That it is one of the

Nymphalidæ and belongs to the tribe *Vanessidi* there can be no doubt; the structure of the subcostal nervure and its branches decides this at once. But this is a large group, and it includes a wide diversity of structural detail. Any one reviewing the matter will, however, be pretty clear that it either belongs in the vicinity suggested above or in the neighborhood of the other fossil butterflies of this tribe from Florissant, near *Symbrenthia* Hübn., and *Hypanartia* Hübn. The fullness of the outer margin, the size of the wing, and the deep sinuosity of the inner margin (the latter feature found in the neighboring genus *Polygonia* Hübn.), tell rather for its relationship to other Florissant fossils; but the length of the costa, giving a more pointed wing, the usual formation of the tip of the wing from the fourth rather than the third superior subcostal nervule (here very decided), with the mode of origin (not altogether unquestionable in the fossil) of the first inferior subcostal nervule, seem to place it rather in the neighborhood of the genera allied to *Anelia* Hübn. In both of these groups the first two superior subcostal veins arise near together, generally a little before the middle of the wing, while the third and fourth are far removed and distant from each other; but it is more common in the *Cirrochroa* or *Anelia* group for both of the first two, the second as well as the first, to arise, as here, before the end of the cell, even if the cell is short; and, as here, for the cell to extend as far along the costal as along the median system, if not indeed further. It would therefore appear that the weight of evidence is decidedly in favor of the alliance of *Apanthesis* with *Cirrochroa* and *Anelia* rather than with *Hypanartia* and *Symbrenthia*. Both of these groups, or rather series, are East Indian as well as tropical American in their distribution, but it is remarkable that *Anelia* is the only genus of the series which occurs in tropical America, where only it is found; while our fossil appears to be more nearly allied to the other genera about *Anelia* rather than to *Anelia* itself. I judge, therefore, that *Apanthesis* and *Anelia* belong to a fading group (for America), and the generic name has been chosen in accordance with this belief. It differs from all of the genera of this series in the origin of the second subcostal nervule some distance before the end of the cell, in the great length of the cell, in the distance of the subcostal nervure from the margin (in both these two last points *Anelia*, of all others, agrees best with it), and in the total lack of falcation to the wing from the fullness of the outer border. It differs entirely from *Anelia* in the course of the so-called discocellular veins, in the approximation of the costal to the subcostal nervure, and in the sinuosity of the inner margin, the last feature seen in a slight degree in *Cirrochroa*. In no one of the genera of this series, nor in those allied to *Hypanartia* (in the latter case, one may add, living or fossil), do I find any such pattern in the fore wing as occurs in *Apanthesis*. The nearest

approach to it is found in some species of *Cirrochroa*, such as *C. fasciata* Feld., of Sumatra, but that is still far removed. It may be said, however, that both in *Cirrochroa* and *Anelia* the more frequent markings generally are strictly parallel as here to the outer margin (though usually dark on a light ground), while in the genera of the other series they are ordinarily more or less at right angles to the costa.

APANTHESIS LEUCE,[1] sp. nov.

(Pl. LII, Figs. 12, 13.)

The ground color of the fore wing is a rich dark fuliginous brown, infuscated narrowly along the costal margin, and with the veins marked in fuscous. Parallel to the margin and at about three-fifths the distance from the apex of the cell to the margin is a connected series, broken only by the nervules, of pale transverse spots, arcuate or doubly arcuate on the lower interspaces, angulate on those beyond the cell, in all the larger interspaces at least twice as broad as long, reaching from the tip of the third superior subcostal nervule to the submedian. Midway between this band and the margin is a faint series of submarginal pale cloudings, scarcely definite enough to be called spots, of the same general form as those preceding them, but smaller and disconnected.

Length of fore wing, 34.5^{mm}; breadth of hind margin, 23^{mm}; length of cell, 17^{mm}.

Florissant; one specimen, No. 16,354, collected by D. P. Long.

Subfamily LIBYTHEINÆ.

PROLIBYTHEA (πρώ Libythea), gen. nov.

The *Libytheinæ* form one of the most strongly marked and eccentric types of butterflies, the position of which has been a matter of some dispute among naturalists. The group is especially remarkable for the excessive length of the palpi, the antigenic structure of the fore legs, and the pieridiform larvæ. It seems to be rather the prevailing fashion now to consider them as a group of *Lemoniinæ* placing them next the *Nymphalidæ*, this opinion being based almost exclusively on the character of the fore legs. Others, whose opinion I share, would place them in the *Nymphalidæ*, in the position nearest to the *Lemoniinæ*, giving greater weight to the other general features of their structure, and particularly to the width of the head between the eyes. It is really only a question of which side of the boundary they shall be placed.

Without exception, authors have referred the species of this group, which are few in number, widespread, and have a characteristic common facies, to a single genus, *Libythea*. Other names, indeed, have been proposed for the genus, such as *Hypatus* and *Hecaerge*, but with the purpose of their including all the species of the subfamily.

[1] Leuce was a nymph beloved of the god of the nether world.

Recognizing, many years since, by a comparative study of the European and American species, that they at least belonged to distinct genera, I proposed[1] that one of the other names (*Hypatus*) should be preserved for the American forms, while the European species should be considered the type of *Libythea* proper.

The distinctions between *Hypatus* and *Libythea* have, however, never been given. These distinctions are now pointed out in the subjoined table, it being understood that all the known American species fall under *Hypatus*, while of all the O:d World types, having autoptically studied only the European species (and *L. myrrha* and *L. lepita* in part), I am unable to say whether all the Asiatic and African forms fall under *Libythea* or not; but the brevity of the palpi of such as have been figured as well as their color pattern certainly indicate that they can not be classed with *Hypatus*. They are, therefore, left out of consideration in the following tabular view of the distinctions between the gerontogeic and the American species.

LIBYTHEA.	HYPATUS.
IMAGO: *Antennæ* stout and very gradually incrassated, so that the club is nowhere marked, but may be said to occupy about half the entire length of the antenna, terminating very abruptly, not more than two joints being concerned in the diminution in size.	IMAGO: *Antennæ* slender, the club well marked, composed of about one-third of the joints, but in length about one-fourth or even less of the whole antenna, the last four joints included in the apical diminution in size.
Palpi: Second joint as long as the width of the head, including only one of the eyes; apical joint about one-fourth lon;er than the second.	*Palpi:* Second joint as long as the wiath of the head, including only one of the eyes; apical joint twice as long as the second.

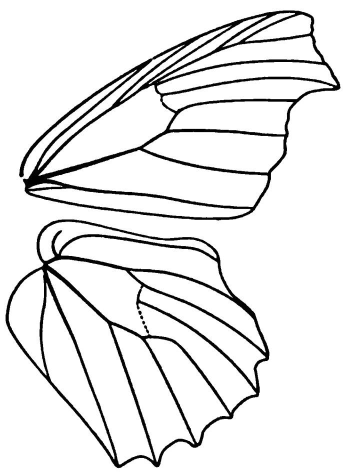


FIG. 20. Showing neuration of Libythea celtis (Fuessly).?

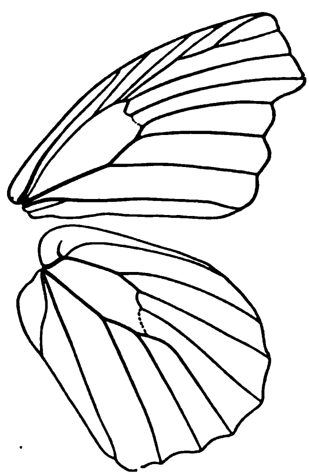


FIG. 21. Showing neuration of Hypatus Bachmanii (Kirtl.).?

[1] Hist. sketch gen. butt.: Proc. Am. Acad. Sci., new series, vol. 2; whole series, vol. 10, 1874–'75 (1875), pp. 194, 206.

Fore wings (Fig. 20) with the last two superior subcostal nervules originating near together, midway between the cell and the apex of the wing, fully twice as distant from either as from each other; upper median interspace nearly as broad at base as at apex; outer margin sharply angulate at the lowest subcostal nervule, below which it is scarcely crenulate.

Color-design of fore wing, beyond the basal patches, formed of a pair of spots depending from the costal margin nearly half way from the cell to the apex, and a subapical patch just above the median nervules.

Hind wing with a pronounced rounded lobe above and at the apex of the costal nervure; outer margin angulato-crenulate, the projections at the nervules; anal angle at the tip of the submedian nervure rectangular.

Eighth abdominal segment of male deeply bifid, the two sides produced to a pair of tapering processes; male claspers forming a pair of elongated, irregular, prickly incurved forceps.

CATERPILLAR uniformly cylindrical throughout.

CHRYSALIS with the anterior extremity simple, there being no apical notch dividing the head.

Fore wings (Fig. 21) with the last two superior subcostal nervules originating rather far apart, dividing the subcostal nervure beyond the cell into three subequal portions; upper median interspace narrowing considerably toward the base; outer margin bluntly angulate at the lowest subcostal nervule, below which it is crenulate, the projecting portions in the interspaces.

Color design of fore wing, beyond the basal patches, consisting of an oblique band or series of adjoining spots depending from the costal border immediately beyond the cell, a subapical patch in the upper median interspace and another in the upper inferior subcostal interspace; the whole series nearly encircling the region occupied by the markings in *Libythea.*

Hind wing with the costal margin altogether entire, there being not the slightest prominence at the tip of the costal vein; outer margin gently crenulate, the projections at the nervules; anal angle before the tip of the submedian nervure rounded.

Eighth abdominal segment of male laterally angulate, the middle produced to a large tapering hook; male claspers forming a pair of broad and unarmed flattened valves or plates.

CATERPILLAR cylindrical, but thickened on the thoracic segments.

CHRYSALIS with the anterior extremity notched, and so furnished with a double protuberance.

The wide distribution of this type of butterflies is, considering its poverty in forms, most remarkable. They are found on every continent, though they are confined to the tropics and the adjacent countries. The metropolis of the group appears to be the archipelago and borders of continents lying between India and New Caledonia, but species also occur in Ceylon, Mauritius, western Africa, and on the shores of the Mediterranean; in the New World they are found exclusively east of the Cordilleras, between the equator and 45° north latitude, including the tropical islands.

Considering the oddity of this type of butterflies and their curious distribution over the world, it is interesting to find not only that the fossil we have next to discuss falls in this group, but that it combines in its structure features which are characteristic, now of *Libythea,* now of *Hypatus.* Following in the order of distinctions given above,

we find it has very slender antennæ (Pl. LIII, Figs. 4, 5, 6, 8), with a distinct though greatly elongated club, comprising about a fourth of the whole antennal length, by which it is distinctly allied to *Hypatus*. On the other hand, when we consider the palpi (Figs. 6, 8) we find them modeled on the plan of *Libythea*, with a comparatively short apical joint, which (if we assume the length of the middle joint to be, as in both the modern genera, equal to the width of the head, including only one eye) is only a third longer than the second joint. In the neuration of the fore wing it most resembles *Libythea* in that the outer two superior subcostal nervules are approximate at base, though in other features of their position they differ from both. In markings it is plainly closer to *Libythea*, since the oblique band depending from the costal margin is well removed from the apex of the cell (Fig. 9) and the lower submarginal patch is above the medium interspaces. The hind wing (Fig. 9) has a pronounced costal lobe above the apex of the costal nervure, thus resembling *Libythea*, and, as there, what portion of the outer margin is preserved is heavily crenate; but the anal angle falls in the medio-submedian interspace, as in *Hypatus*, and not at the apex of the submedian nervure as in *Libythea*. None of the other features distinguishing *Libythea* from *Hypatus* can be made out; but enough has been said to show the remarkable intermingling of characters, and to prove that we have here, in all probability, the common ancestor or one of the immediate ancestors of both the modern genera. There must, however, have been more than one stage between it and our existing American species. As it plainly can not be considered in strictness a member of either, and has some characteristics of its own, besides a wholly different combination of characters from the living forms, I propose for it the name of *Prolibythea*. Its distinctive features, besides those above mentioned, which it shares with one or the other of the modern types, are the extreme slenderness and brevity of the antennæ, which are even slenderer than in *Hypatus* and are rather less than two-fifths the length of the fore wing; the point of origin of the outer two superior subcostal nervules of the fore wings, the outermost being midway between the cell and the apex, instead of being about as far beyond that point as the penultimate is before it, as is the case both in *Libythea* and in *Hypatus*; and finally in the indication of an excessively dentated margin to the hind wings, at least posteriorly. The bulk of its features are thus seen to bring it into much closer alliance with *Libythea* than with *Hypatus*, and we have the curious circumstance of a Tertiary butterfly from the heart of North America belonging to a group of which only a widely dissevered fragment now exists dispersed all over the globe, yet a butterfly which is more nearly allied to forms existing now in distant parts of the earth, separated from its ancient home by wide oceans, than to forms of the same stock on the same continent.

I might add that an examination should be made especially of the African *Libythea labdaca* Westw., the only modern species agreeing with the fossil in size, to see whether it should not fall in *Prolibythea.* As figured in Doubleday and Westwood's Genera of Diurnal Lepidoptera, it differs decidedly from other species, and seems to agree more closely than any other to our fossil (see page 469). The antennæ are represented as almost precisely like those of the fossil, being exceedingly slender, about two-fifths the length of the fore wings, with a distinct and comparatively short club, and the shape of the margin about the anal angle of the hind wings with apparently the termination of the submedian nervure is identical with the fossil species and quite different from the same part in all other species of which I have seen specimens or illustrations.[1]

PROLIBYTHEA VAGABUNDA, sp. nov.

(Pl. LIII, Figs. 4-9.)

The specimen to which this name has been given shows the body and appendages of a butterfly lying upon its back (Pl. LIII, Fig. 4). The antennæ and wings of the left side (as seen) are lost and the specimen itself has been twice broken across, to the loss of small portions of the wings. The wings overlap almost completely, and such markings as they may have had are exceedingly obscure; but the greater part of the neuration and some important features of the color pattern can be made out (Fig. 9), together with most of the margins, though the outer margin either received severe abrasion before sepulture or is imperfectly exhibited through the conditions of deposition. The palpi, one antennæ (Figs. 5, 6), and parts at least of nearly all the legs are preserved, the nature of the front pair (Fig. 7) showing, with the very full and equal abdomen, that the specimen was a female.

Most of the features of its structure are such as have come into notice in discussion of its generic relations, but a few further details which are more specific in nature may be added. The fore wing has the costal margin very regularly and gently convex; that the outer margin is produced to a sort of falcation at the lowest inferior subcostal nervule, as in all existing members of the subfamily, is shown by the course of the margin above and below that point; but whether this falcation is as strong as in *Libythea* proper, as made to appear in the restoration (Fig. 9), is not certain; it is clearly emarginate above this point, however, and not, as in the modern African species, entire. In the hind wing the costal margin is preserved entire, and is formed on the general fashion of that of the Mediterranean *Libythea celtis*, although the lobe is not so prominent and

[1] I have seen all but the species of Mauritius, Ceylon, and one of those of the Malay Archipelago.

... the wing
... subcostal
... the wing at
... but by the
... border.
... of our
... with the
... of the
... wing
... defi-
... ex-

... one
... the
... a

esting to note that Lesquereux has found among the plants of Florissant two perfectly well preserved leaves of a very fine Celtis (*C. Maccoshi* Lesq.), whose generic relations are positively ascertained. With them were also found fragments of flowers which could have been readily admitted as of the same species. It is, therefore, highly probable that *Prolibythea vagabunda* fed on *Celtis Maccoshi.*

The specific name is in allusion to the far-away immediate allies of the fossil, and its relation to a vagabond type.

Florissant, one specimen, No. 16,353.

Family PAPILIONIDÆ.

Subfamily PIERINÆ.

Tribe PIERIDI.

STOLOPSYCHE (στόλος, ψύχη), gen. nov.

A medium sized pierid, with small head, rather large thorax, and ample wings. Front of head clothed with a rather thin mass of rather short hairs not reaching beyond the base of the apical joint of palpi. Antennæ (Pl. LIII, Fig. 2) slender, about two-fifths as long as the fore wing, all the joints remarkably short, and those just beyond the base no longer than broad, the very slender and very gradually enlarged club occupying nearly a third of the whole antenna. Palpi (Fig. 3) very slender and exceptionally long, being two and a half times as long as the eye, the apical joint nearly double the middle in length, and considerably exceeding the basal joint, the two basal joints furnished beneath with a thin fringe of long hairs, rather longer below than above.

Fore legs only a little shorter than the middle pair, the tibiæ being from three-fifths to two-thirds as long as the femora, and about equal to the first joint of the tarsi or the remaining joints combined.

The small head combined with the large and arched thorax and long fore legs, show that this insect must belong to the *Pierinæ*, and its slender, long, and porrect palpi mark it as referable to that division of it, the *Pieridi*, to which the "Whites" belong—a conclusion well borne out by the length of the apical joint of the palpi and the character of such ornamentation as it has, while the structure of the antennæ is more nearly allied to that of the *Rhodericidi.* It seems to agree well in general appearance, size, and in the proportions of the fore legs with *Pieris*, using this term in the most restricted sense, and to be indeed more closely related to it than to any other living genus of *Pieridi;* but it differs strikingly from it and from all others in the excessive length of the labial palpi, the extreme brevity of the basal antennal joints, and the character of the club. In the latter point it certainly shows a passage toward Eurymus. Little direct comparison can be made between it and the only other known fossil butterfly

of this group, *Pontia freyeri* (Heer) from Radoboj, since the only fragment of that species consists of a wing, while here the wings are not only incomplete, but are badly preserved. It is, however, highly probable, from the absence in this fossil of the *Pontia* pattern of that from Radoboj, that the two are generically distinct, though they are doubtless nearly allied. The neuration is badly preserved in both.

STOLOPSYCHE LIBYTHEOIDES, sp. nov.

(Pl. LIII, Figs. 1–3.)

The species is represented by a single specimen, the wings of which are badly preserved and the outer margin broken off, though parts of the body sufficient for generic determination can be made out with pains. The insect appears to have been about as large as *Pieris rapæ* Linn., but with relatively smaller head, larger thorax, and much larger palpi, and to have possessed wings generally resembling those of *Pieris* in form excepting in having a less arched costal margin. In markings the wings seem to have been white, or at any rate very pale, and on the under surface of nearly uniform coloration, with no blotches or spots of darker color anywhere (such as occur in the fore wing in the median or submedian interspaces in *Pieris rapæ*, or depending from the costal margin at the apex of the cell in *Pontia* or *Neophasia*), but to have had all its markings confined to the nervures or margins, and, with the exception of a moderately broad costal edging, to the nervures of the hind wings, all of which, like the costal border of the fore wings, appear to have been traced in grayish or griseous streaks. Whether, as in *Ascia* and some others, there was any black edging to the outer margin or an apical patch can not be told, as the stone is broken so that the outer margin is not preserved.

The probable length of the fore wing was 25^{mm}; length of palpi, 4.5^{mm}; of antennæ, 10^{mm}; of fore tibia and tarsi, 7.2^{mm}; of middle tibia and tarsi, 8.5^{mm}.

The specific name is in allusion to the great length of the palpi.

Florissant, one specimen, No. 11,077.

APPENDIX.

After this paper was written, I learned that a single specimen of the little known *Libythea labdaca* of West Africa was in the collection of Rev. W. J. Holland, of Pittsburgh; and he has kindly taken the greatest pains to answer all my questions regarding its structure, and of his own motion to send me excellent enlarged sketches of different organs. From these I find that my conjecture that of all living forms it would be found nearest the fossil *Prolibythea* proves entirely correct. The antennæ are remarkably slender, with a distinct club, composed of about 14 to 15 joints, and comprising not more than one-fifth of the whole antenna, which is itself just two-fifths the length of the fore wing; the terminal joint of the palpi is nearly if not quite twice as long as the middle joint; the last two superior subcostal nervules of the fore wings are widely separated at base; and the base of the upper median interspace of the fore wings is considerably narrowed, though not to a great distance. In all these characters it agrees with *Hypatus*, and not with *Libythea;* in all (excepting, perhaps, the characteristic of the upper median interspace, which is unknown in the fossil) it agrees entirely with *Prolibythea.* It also agrees with *Prolibythea*, and with *Libythea* rather than *Hypatus*, in the more nearly entire margin of the lower half of the fore wings and the distinctly crenulate outer margin of the hind wings. It is allied to *Prolibythea*, and to neither of the modern genera mentioned, in the tail-like prolongation of the lower median nervule of the hind wings. In the termination of the submedian nervure of the same wings, rather within than at the anal angle, it comes betweeen the European and American (fossil and recent) forms; while in only one feature, the entire, unlobed costal margin of the hind wings, does it agree better with *Hypatus* than with *Prolibythea.* These peculiarities show that it is more nearly allied to *Prolibythea* than to any modern genus; it should not, however, be referred to that extinct type—not simply on account of the differences in the margins of the wing mentioned above, but for several features in the wing-structure, in which it disagrees with all modern types (Fig. 22). In the fore wings, the outer margin is peculiar in the near approach to parallelism of the portions above and below the sudden change of course above the upper median nervule common to all *Libytheinæ*; the last two superior subcostal nervules are very far apart, the middle of the thirds into which they divide the subcostal nervure beyond the extremity of the cell being longer than either of the other (subequal) thirds, while in all other *Libytheinæ* it is shorter; the form of the outer half of the hind wings is wholly peculiar, due to the prominence of the upper sub-

costal region and the subtruncate though distinctly crenulate margin below it; the tail-like character of the prominence at the end of the lower median nervule is more marked than in *Prolibythea*, and wholly different from any modern type; in both wings the cells are of unusual length, while the color-pattern of the outer half of the fore wings is sui generis. There is a small spot next the costal margin, about one-third way from the cell to the tip of the wing; a pair of similar spots in the inferior subcostal interspaces, more than halfway from the cell to the outer margin; and in the median region an oblique macular band, midway in direction and in distance between the median nervure and the outer margin. These differences forbid its admittance into any of the genera mentioned above, and I therefore propose that it should bear a new name, *Dichora* (δὶς two, χώρα country), to signify its peculiar and highly interesting geographical affinities. I know of only this one species, *D. labdaca* (Westw.), from the western coast of Africa.

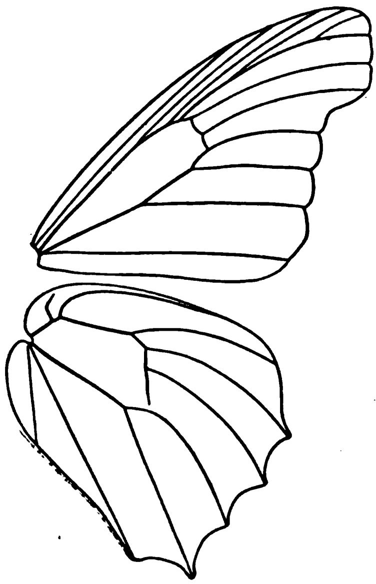


Fig. 22.—Showing neuration of *Dichora labdaca* (Westw.) ?

PLATE LII.

FIG. 1. PRODRYAS PERSEPHONE; showing the left half of the body in outline with the venation and the position of the markings, the wings being separated slightly more than in the specimen, to allow the venation to be more readily distinguished. $\frac{2}{1}$

2. THE SAME; showing the left antennal club, the naked being clearly distinguished from the squamous portion. $\frac{4}{1}$

3. THE SAME; the club of the right antenna, turned in the fossil so as to show only the squamous side. $\frac{4}{1}$

4. THE SAME; the palpi, magnified. $\frac{15}{1}$

5–9. THE SAME; scales from different parts of the right fore wing, those of Fig. 5 occurring between the lowest subcostal spot and those in the subcosto-median interspace; Fig. 6 in the basal half of the upper submedian interspace just before the spot; Fig. 7 some scales close to the apex of the wing; and Fig. 8 on the costal margin, half way between the outer row of spots and the tip. The figures are drawn as they appear reversed under the microscope. $\frac{100}{1}$

10. THE SAME; showing the whole fossil. $\frac{1}{1}$

11. LITHOPSYCHE STYX; showing the margins and veins of the overlapping wings and the edges of the spots as they appear on the wing as preserved. $\frac{2}{1}$

12. APANTHESIS LEUCE. $\frac{1}{1}$

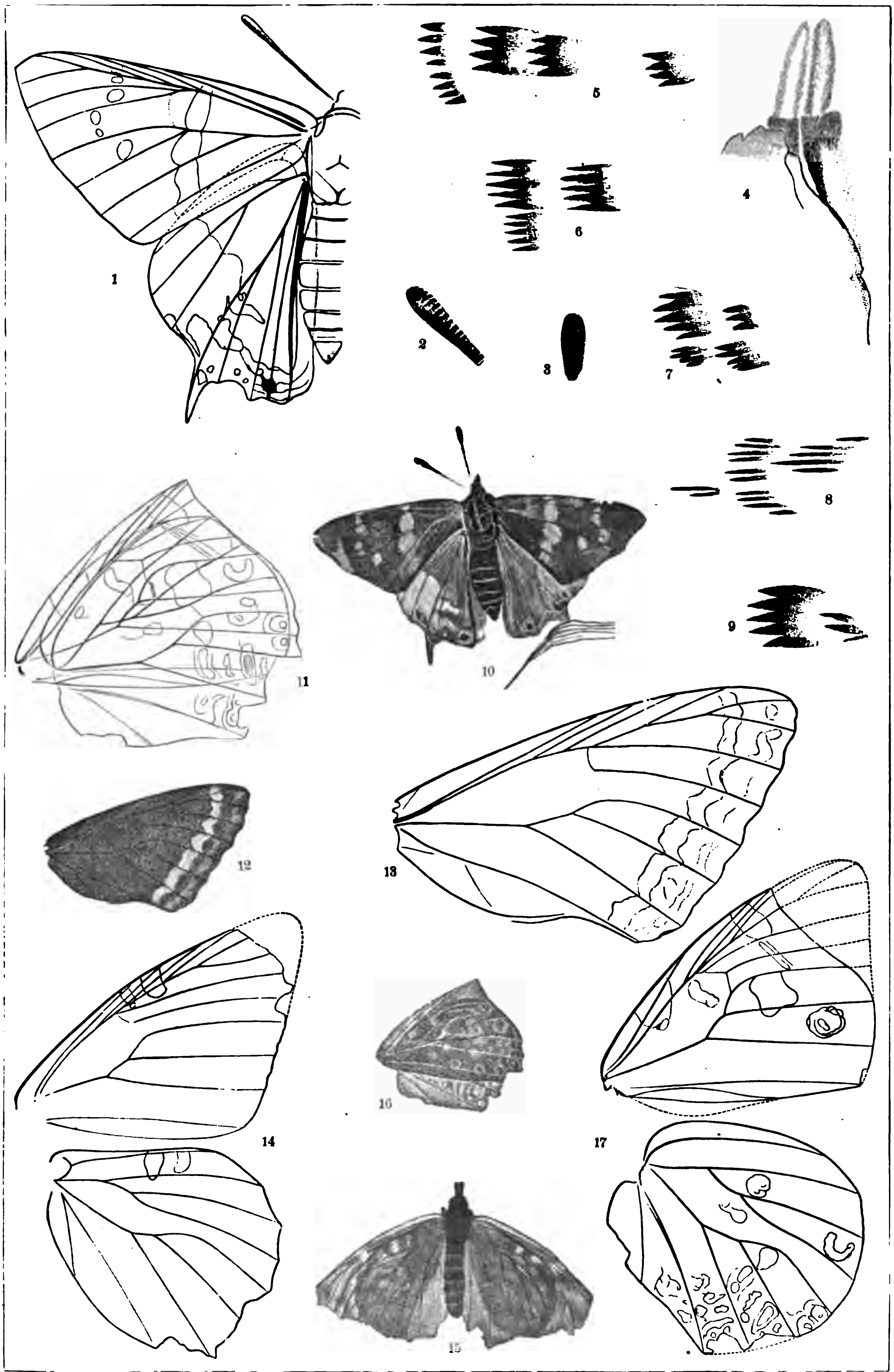
13. THE SAME; showing the venation and the position of the markings. $\frac{2}{1}$

14. JUPITERIA CHARON; the venation and margins of the separated wings, with the limits of such markings as are unquestionable. $\frac{2}{1}$

15. THE SAME; showing the appearance of the fossil with its overlapping wings. $\frac{1}{1}$

16. LITHOPSYCHE STYX; the specimen as it appears. $\frac{1}{1}$

17. THE SAME; showing the margins, markings, and venation of the separated wings, with the tip of the fore wing restored. $\frac{2}{1}$



THE FOSSIL BUTTERFLIES OF FLORISSANT, COLO.

PLATE LIII.

FIG. 1. STOLOPSYCHE LIBYTHEOIDES. $\frac{2}{1}$

2. THE SAME; showing more details of the structure of the antennæ, palpi, and legs. $\frac{4}{1}$

3. THE SAME; the palpus, as it would appear if denuded. $\frac{4}{1}$

4. PROLIBYTHEA VAGABUNDA. $\frac{3}{1}$

5. THE SAME; showing the details of the structure of the antennal club, as far as they can be made out. $\frac{10}{1}$

6. THE SAME; showing the head and its appendages. $\frac{4}{1}$

7. THE SAME; the fore leg, showing spines and terminal claws. $\frac{10}{1}$

8. THE SAME; drawn in outline to show the veins as they appear in the overlapping wings of the fossil, with the position of the other features of the body. $\frac{2}{1}$

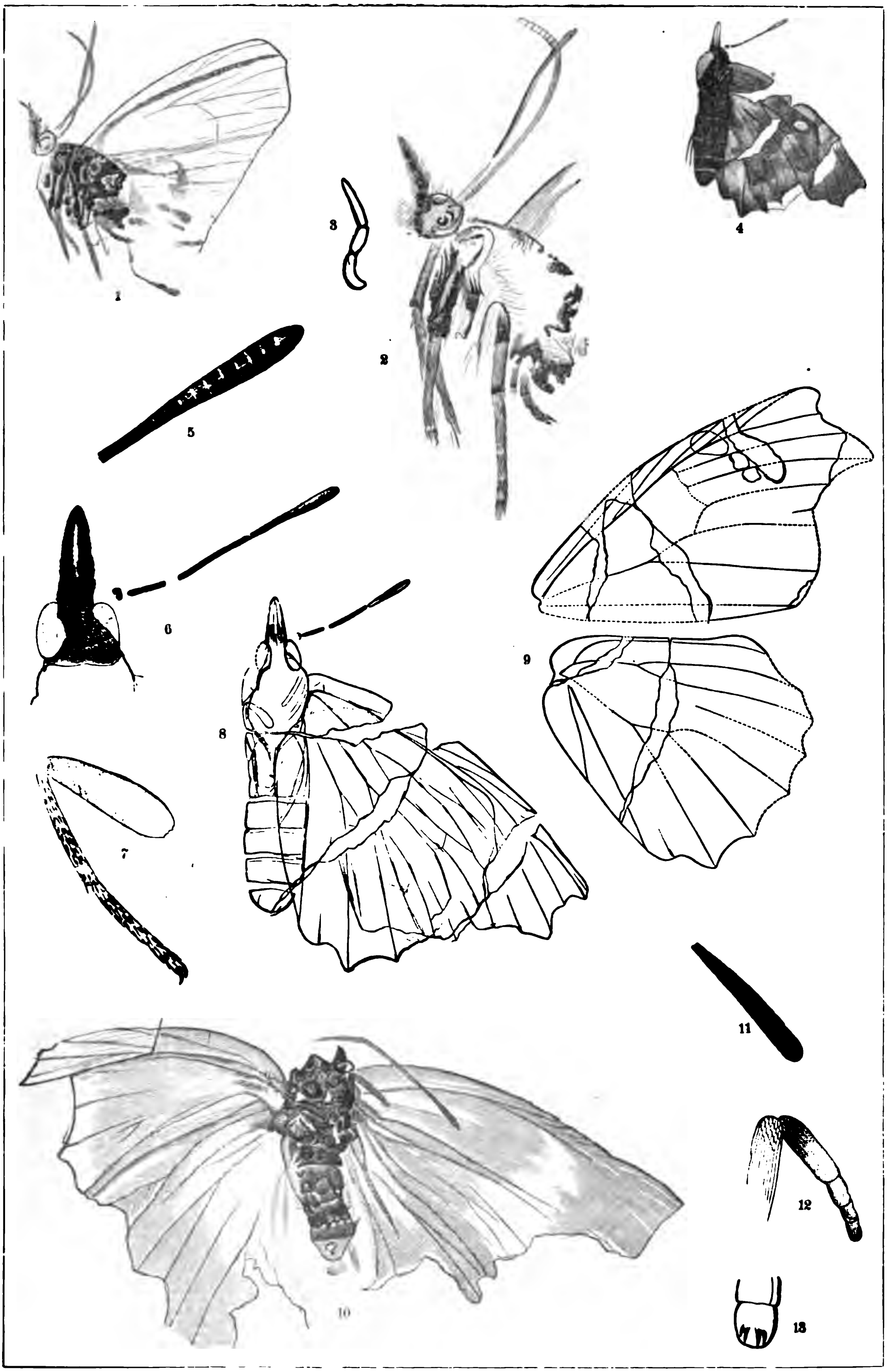
9. THE SAME: the wings detached, and the venation and margins shown separately and thus clearly; dotted lines indicate the parts which are restored. $\frac{2}{1}$

10. NYMPHALITES OBSCURUM. $\frac{2}{1}$

11. THE SAME; the club of the antenna enlarged to show its composition. $\frac{8}{1}$

12. THE SAME; the front leg, with the tarsal joints. $\frac{6}{1}$

13. THE SAME; the terminal tarsal joint of the fore leg, showing the spines which take the place of the normal claws. $\frac{20}{1}$



THE FOSSIL BUTTERFLIES OF FLORISSANT, COLO.

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Y.

Z.